American Railway Engineering and Maintenance-of-Way Association.

BULLETIN NO. 14. MARCH, 1901.

REPORT OF COMMITTEE No. 5.—TRACK.

To the President and Members of the American Railway and Maintenance-of-Way Association:

Your Committee has necessarily been unable to cover all of the subjects assigned to it, and the reports that are submitted are preliminary only, and as there has been no meeting of the Committee the report is composed of individual expressions of its members. As much more time than the Committee has been able to devote to these subjects is needed to prepare a comprehensive report on all of them. The work of the Committee has been delayed by reason of the resignation of the Chairman, and the recent resignation of four other members.

MAINTENANCE OF LINE.

By H. C. Landon.

With the increased speed of locomotives and trains comes the demand for a nearer perfection of line on tangents and curves. The permanency depends, first, upon the soil where the track is laid, and then upon the character and amount of ballast. The foundation of all track being the earth as we find it, no matter what ballast is placed thereon, it is impossible to construct a road and perfectly maintain the line excepting at points where it passes over permanent structures that are set upon foundations where no settlement is possible. The approach toward perfection in line and the maintenance of the same depends entirely upon the character of the ballast and the amount of traffic which goes over it.

A road having light traffic and light locomotives and comparatively slow passenger trains is not called upon to try for that perfection of line that is necessary for a road having heavy traffic and using heavy equipment. At all times such line and surface should be maintained that it is perfectly safe for the traffic that is moving over it.

Where the passenger business is light and passenger trains are comparatively slow and where most of the business is freight, if the track is slightly out of line it does not affect the comfort of passengers, nor is there any particular danger of damage to freight traffic. If it was endeavored to keep such track in perfect alignment, the expense would be a waste rather than an economy. There should be, however, a tendency, no matter what the traffic may be, toward getting the line

in the best possible shape under the conditions. The track, as originally staked out, does not at all points remain as laid, nor is track laid always with the proper care. Center stakes are not followed, and frequently in tracing the old line it is found that track has moved from between 1 to 2 feet or more, either from the settling of the tracks, or by the trackmen's lining bars. This deviation from the original line on curves often produces sharp places which cause a disagreeable throw.

Of 19 roads replying to the circular sent out by the Committee, 10 set center stakes with the transit, placing them from 100 to 200 feet apart, so as to move the track as little as possible, on tangents. The track is thrown to center stakes by trackmen in the most convenient season, and this is ordinarily when the road is being re-tied, or ballasted. Tangents are thrown then to exactly straight line. There is a good deal of labor saved in this method of lining, as the track is thrown to where it belongs and the work of lining is practically completed as the section gang goes over it.

One side of the track, east or west, north or south, or rail on the mile-post side is usually taken for the line side of the track by the foreman in re-aligning the track. Where the tangents are short and the curves re-aligned, the tangents are frequently lined by the eye between the points of curves. Track lining should, if possible, be done before surfacing.

Curves should be adjusted in the same manner as tangents; center stakes should be set. Sixteen roads out of the 19 make it a practice to put curves in proper line by setting stakes with the transit. While none of them so state, it is presumed that the work of throwing or adjusting track after the stakes are set is done when the track is being worked over. Very poor alignment can be greatly improved by the introduction of easement, or spiral, curves, and by their judicious use these improvements can usually be made without varying from the old alignment sufficiently to have the track itself on a new roadbed.

Fourteen roads out of the 19 use some form of easement curve. One road states that having found no particular advantage in the easement curve, its use has been abandoned. It would seem, however, from the large number of roads using easement curves, that some form of easement curve is necessary to obtain the best results.

Three roads use some form of the "Searles" spiral, 2 roads use some form of the "Holbrook" spiral, and 1 road uses the cubic parabola. Any form of curve which gradually changes the degree of curvature will probably answer, but that form of spiral which changes the curve and makes a long and easy approach to a curve will give the best results. One railroad uses the form of the "Holbrook" spiral, which changes 1 degree in every 100 feet of its length, as its standard. Sharper easements are used when it is necessary. This makes a very easy approach to a curve, as the elevation changes very gradually. The Erie Railroad did use for its standard a spiral changing 1 degree in every 60 feet. This spiral makes a light and easy change from tangent to curve. The change in curvature and elevation is light and easy. With this spiral, at a speed

of 40 miles per hour, a train will pass over 1 degree of curvature, and, say, 1 inch of change in elevation per second. Even at the rate of 60 miles per hour it would pass through the same distance in about two-thirds of a second. At the rate of 60 miles per hour, this easement curve would produce no ill-effects, although for a rate of 60 miles per hour a lighter easement than 60 feet per degree is desirable, and should be used where practicable. Where conditions have made it necessary, spirals changing 1 degree every 15 feet have been used to advantage with speed of 45 miles per hour.

Generally the easement curves are used and applied to all curves of 2 degrees or more and between parts of the compound curve where curvature differs more than 2 degrees. Stakes in the easement curve should not be set farther apart than 25 or 30 feet.

The labor of locating an easement curve is but little more than that of the circular arc. It is advisable, on high-speed lines, to use easements with curves of 1 degree and over. On the "Vandalia" line, curves of 30 minutes or more are eased with the "Holbrook" spiral.

Transition curves enable the elevation to rise uniformally as the curvature increases. If the circular arc is at the proper elevation, then the train movement passes from the tangent to the circular arc uniformly with the increase in elevation.

The perfect line is probably unknown. It is the endeavor, in order to realize the best service, to attain as nearly perfect alignment as possible. Maintenance of line depends upon foundation.

Tangents and curves should be laid to exact line and curvature, allowance being made for expansion, and the track accurately gauged. Careful gauging of track materially helps in the maintaining of line. The surface must also be maintained. The track level should always be used in surfacing track. This is not always insisted upon, or not always done.

Vertical Curves.—Vertical curves in some form are used on all roads connecting the different gradients. The Vandalia Railroad uses the following:

The vertical curve shall consist of as many chords as there are whole tenths of a foot in the algebraic difference between the two gradient lines, less one. The length of chord shall generally be 100 feet. The change from one gradient line to another shall be made by a variation in rate of grade for each chord equal to the algebraic difference between the rates of the two gradient lines, divided by the whole number of tenths in the algebraic difference; this change of rate is approximately 0.1 feet per chord.

To change from the grade of plus 0.6 per 100 to a grade of minus 0.5 per 100. Number of chords in a curve are 11 minus 1, equal 10. Length of curve 10x100, equal to 1,000 feet. Rate of change from chord to chord equals $\frac{1.1}{11}$ equals 0.1.

Rate	of grade	on	first	chord equals	plus	0.5
"	"		second	" "	"	0.4
"	"		third	" "	"	0.3
"	"		fourth	" "	"	0.2
"	"		fifth	" "	"	0.1
"	"		sixth	" "	"	0.0
"	"		seventh	" "	minus	0.1
"	"		eighth	" "	"	0.2
"	"		ninth	" "	"	0.3
"	"		tenth	" "	"	0.4

If it is necessary for any reason to change the length of the curve the change is made in the length of chord, the rate of change remaining the same.

Ordinarily the changes of vertical curves are made from 500 to 1,000 feet, depending upon the local conditions, but some approximate uniform curvature or change should be assumed in making the change from one gradient to another.

The proper method of tamping depends upon the character of ballast used. If gravel, cinders or natural soil are used for ballast, the track shovel seems to give the best satisfaction as a tool for tamping. For rock ballast the tamping pick is generally used. Some roads use track shovel provided with iron handle and this iron handle is used for tamping the cinders or earth compactly under the tie. Other roads use a tamping bar, a separate tool altogether, for tamping ballasted track.

The Chattanooga, Rome & Southern rules in the Maintenance-of-Way Department in reference to tamping are as follows:

In surfacing track, raise the ties as little as possible off the old bed. To get level track on tangents and the proper elevation on curves, except where there are small dips in grade not exceeding 6 inches, these must be taken out; any exceeding 6 inches will be taken out by special instructions. In raising track the dirt must be thoroughly tamped under each tie from a point 18 inches inside of rail to end of tie. Special attention must be given that the tie is tamped directly under the rail, which, because it is a difficult point to reach, is apt to be neglected by the men. Tamp all ties as evenly as possible, and always tamp the joint ties last. The level must be used constantly, not only at each joint and center. In using track jacks they must always be set on outside of rail. Good track means track that is level on tangents and properly and evenly elevated on curves.

The dirt must always be packed hard around the ties in filling in, and to do this pack with feet, layer by layer, so that the water will turn off quickly instead of seeping through bed of tie, causing the track to churn. After track is surfaced dress off as follows:

Dress dirt level with top of tie to 18 inches on each side of center, then slope to 1½ inches under rail and then to bottom of tie ½ inch from each end, then to bottom of standard ditch.

The general rules of the Chicago, Milwaukee & St. Paul are as follows:

Track should be surfaced at least once a year, so as to give it a uniform bearing. When surfacing, a track level must be used. When track is laid "Square Joints" all joint ties must be tamped solid for a distance

of 16 inches on inside of rail to end of ties. Center of ties must be tamped loosely, so as to prevent track from becoming center bound. Before the close of each day's work, track should be brought to exact line, and properly dressed up. In no case must track be left over night without being properly filled in and dressed up. When track jacks are used, they must invariably set on the outside of rail. On straight lines, except where they approach curves, the tops of rails must be level with each other.

From the replies received from the different roads, in reference to tamping, it seems to be the general opinion that the tamping should be thoroughly done, from the end of the tie to from 12 to 14 inches from the inside of rail, and the center of the track with very little or light tamping should be done.

THE HOLBROOK SPIRAL.

Of 23 roads replying to Circular No. 16, on Track, 14 roads use some form of spiral curve. Two roads report using the Holbrook Spiral, 3 roads the Searles Spiral, and 1 road the Wellington Transition Curve. It is possible that a greater number use some form of spiral, but do not so state. It is evident that the use of some form of easement curve is recognized as necessary to secure the best track; and in connection with subdivision A, of maintenance of line, the committee thinks a short discussion of the Holbrook Spiral, as first used by Mr. E. Holbrook, and which seems to fill all the conditions of an easement curve, will be of some interest.

The Holbrook Spiral changes uniformly in curvature with the length of arc. There is an exact agreement in the curvature with the curves at connecting points. It can be located and recorded the same as a circular arc. It can be defined by the equation $D = nL$ (1) in which D is the degree of curve in minutes and L is the length of curve in feet; n is a constant which determines the rate of increase in curvature.

The other nomenclature used is as follows:

R equals the radius of the main curve.

i equals the central angle of the spiral arc.

Δ equals the central angle of the whole curve.

d equals the deflection angle from point of curve to any point of the spiral,

$i - d$ equals the back deflection from the tangent at the point of curve to the point of spiral.

y equals the abscissa of any point on the spiral referred to the P. S. point of spiral as the origin and initial tangents as the axis of Y.

For the point H, $y = AE$.

x equals the ordinate of the same point measured at right angles to the above axis.

For the point H, $x = EH$.

y_0 is the abscissa of the PC of the main curve produced backwards, ie., of the simple curve without spiral.

For the point C, $y_0 = AC$ and x_0 equals the offset between the initial tangent and the parallel tangent of the main curve produced backwards of the ordinate of the PC of the produced main curve.

For the point F, $x_0 = C^1$ F.

T equals the tangent distance for spiral and the main curve and equals the distance from A to B intersection of the tangents.

E equals the external distance of the spiral and the main curve.

The Fig. 1 shows the spiral applied to both ends of the simple curve, AH being the length of the spiral at one end,

HJ being the main curve and JM length of spiral at the other end of main curve.

The central angle of the arc whose length is $\frac{}{100}$, whose rate of curvature varies uniformly from O to D is ½ D $\frac{l}{100}$, or substituting

The value of D from the equation D = nL. equation (1).

i equals $\frac{l^2}{200n}$ (2) Reducing this from the angle to the arc by multiplying the length of one minute.

$i = \frac{nl^2}{10800 \times 200n}$ representing the constant factor by a this reduced to $i = al^2$.

The differential equation for x and y in terms of i and l are

$$dx = \sin i.\ \ dl = \sin al^2.\ \ dl \quad (1)$$
$$dy = \cos i.\ \ dl = \cos al^2.\ \ dl \quad (2)$$

Expanding sin al^2 and cos al^2 by Maclaurin's theorem, and integrating the resulting equations, there follows:

$$x = \frac{al^3}{3} - \frac{a^3l^7}{42} + \frac{a^5l^{11}}{1320} - \frac{a^7l^{15}}{75600} \quad (3)$$

$$y = l - \frac{a^2l^5}{10} + \frac{a^4l^9}{216} - \frac{a^6l^{13}}{9360} \quad (4)$$

The deflection angle is $d = \tan^{-1} \frac{x}{y}$ (5).

A close approximation to d is obtained as follows:

Since d is small, the arc may be substituted for the tangent giving $d = \frac{x}{y}$ and as the series for x and y decrease rapidly, the first term of each will give the ratio with all the precision practically required, therefore:

$\frac{x}{y} = \frac{1}{3}al^2$ or $d = \frac{1}{3}i$ (6)

The ordinate x_0 = FC = HE — HN, but HE = X and HN = R vers i, hence:

$x_0 = x$ — R vers i. (7).

A close approximation to x_0 is obtained as follows:

$R = \frac{50}{\text{sm} \frac{1}{2}D}$ or approximately $R = \frac{50}{\frac{1}{2}D} = \frac{100}{D}$, but

$i = \frac{1}{2} \frac{DL}{100} = al^2$, or D = 200 al, hence: R = ½ al. Also,

vers $i = 1 - \cos i = 1 - \cos al^2 = l - (l - \frac{a^2l^4}{2} + \text{etc.})$, or approximately,

$\text{vers } i = \frac{a^2 l^4}{2}$, therefore, $R \text{ vers } i = \frac{1}{4} a l^3$, but since

x is very nearly $\frac{1}{3} a l^3$, $R \text{ vers } i = \frac{3}{4} x$, hence,

$x_0 = \frac{1}{4} x$. (8).

The ordinate $Y_0 = AC = AE - GH$, but $AE = y$ and $GH = R \sin i$, hence

$y_0 = y - R \sin i$. (9).

The above formulas are the formulas necessary for the compilation of the table necessary for use in calculating the table for the applying of easement curves. I give below the necessary formula for use in applying the spiral to simple curves with same spiral at each end.

From the diagram it is very easily known how these formulas are determined, and it is not necessary to go into detail of deriving them here.

In combining the spiral with the circular arc it should be remembered that the circular arc is computed to join the auxiliary tangents distant x_0 from the actual tangents and that the point of spiral P.S. is y_0 beyond where the circular arc joins the auxiliary tangents.

$$T = (R + X_0) \text{ Tan } \tfrac{1}{2} \Delta + Y_0 \quad (10)$$

$$E = \frac{R + Y_0}{\cos \frac{1}{2} \Delta} - R \quad (11)$$

$$R = \frac{T - Y^0}{\text{Tan } \frac{1}{2} \Delta} - X_0 \quad (12)$$

$$R = \frac{E \cos \frac{1}{2} \Delta - X_0}{1 - \cos \frac{1}{2} \Delta} \quad (13)$$

When it is necessary to use a shorter spiral at one end than at the other, the spiral arcs AH and JM are unequal. The auxiliary tangents FP and PK, figures 1 and 2, are unequally distant from the actual tangents. Denoting AC by y_0, CF by x_0, LM by y'_0 and KL by x'_0 we have the following formulas, which are easily derived:

$$T = AB = AC + FP + PZ - LZ = Y_0 + R\tan \tfrac{1}{2} \Delta + \frac{X_0^1}{\sin \Delta} - X_0 \cot \Delta$$

$$T^1 = BM = LM + PK + PU - UR$$

$$T^1 = Y_0^1 + R\tan \tfrac{1}{2} \Delta + \frac{X_0}{\text{SIN } \Delta} - X_0^1 \cot \Delta$$

The angle FOH $= i$ and the angle JOK $= i^1$

$HOJ = \Delta - (i + i^1)$

Where the curves are long and it is unadvisable to attempt to secure a uniform curve, a good line can be secured by light compound curves, then the arc joining the tangents may be eased off by the following method:

A point should be selected in the line as at G, Fig. 3, some 500 or 600 feet from the end of the curve, or closer, if necessary, the tangent G to the curve at that point is determined and the angle of intersection at L is measured as well as the distance LG. Let R′ be the radius of the simple arc GB connecting GL and AL.

With the spiral CA and the circular arc GC when produced must join the auxiliary tangent HD distance, x_0 from AL. Let R be the radius of an

arc to join HD, then $R = R^1 - \frac{X_0}{\text{vers } \Delta}$ reducing as $X_0 = X - R$ vers i, vers $\Delta = 1 - \cos \Delta$, and vers $i = 1 - \cos i$. Making the substitution,

$$R = \frac{R^1 \text{ vers } \Delta - X}{\cos i - \cos \Delta} \quad (16)$$

denoting AB by d we have

$$d = y_0 - (R - R^1) \sin \Delta \quad (17)$$

Since AL = BL + d the point of spiral is thus located at A.

After locating the spiral AC the arc CG is continued, compounding when necessary. At the other end of the curve the same method is pursued in making the easement.

In introducing the easement curve between the parts of a compound curve, the most satisfactory way is to use the easement curve the same as compounding, and fit it in by trial rather than to attempt to locate it by calculation. The formulas that are given are practically all that are required for ordinary practice. For general practice n should preferably be equal to one, giving the 60-foot spiral, if n equals 5-10 we have the 30-foot spiral. The tables given in connection with this, giving the value of D, L, X, Y'_0 and D for intervals of 10 feet for the 30 and 60 foot spiral up to 8 degrees, the other for intermediate values can be interpolated. A table is also given for the 18-foot spiral for intervals of 6 feet n in this case = .3.

It is convenient to have tables tabulated for intervals of 1 foot in length. The functions for the 20 or 40 foot spirals can be taken from the 60-foot spiral by proportion.

On our low grade lines we are endeavoring to make curves uniform, not to exceed 8 degrees. Some of our curves are very irregular, running from 6 to 12 degrees, and it is possible without very much throw in the track, where banks will permit, to make these uniformly 8 degrees. On the mountain line the curvature is very much heavier, running from 18 to 20 degrees. An example of the re-alignment of one of the irregular curves is here given:

The intersection point B was easily located, the angle found to be 32 degrees and 30 minutes. From the point of intersection to center of track was found to be 31½ feet. The banks were wide and it was found that an 8-degree curve with an 18-foot spiral at the other end would fit the conditions very well, and throw the track about 3 feet on a hard gravel bank. Some portions of the curvature were as high as 12 degrees.

The tangent distance $T = (R + x_0) \times \text{tangent } \frac{1}{2} \Delta = 282.2^1$.

AH = JM = 144 ft.

i the deflection in the angle for the whole of the spiral equals 5 degrees 45 minutes.

The point A located by measuring the distance AB, BG 282.2 feet and the spiral AC was then located by deflections.

Spiral was located A to H and from J to M with the 24-foot cord. The total deflection angle $d = 1^\circ - 25'$. The transit was set up at H, and the vernier was set at I — d = 2 deg. 50 min., and then turned on A,

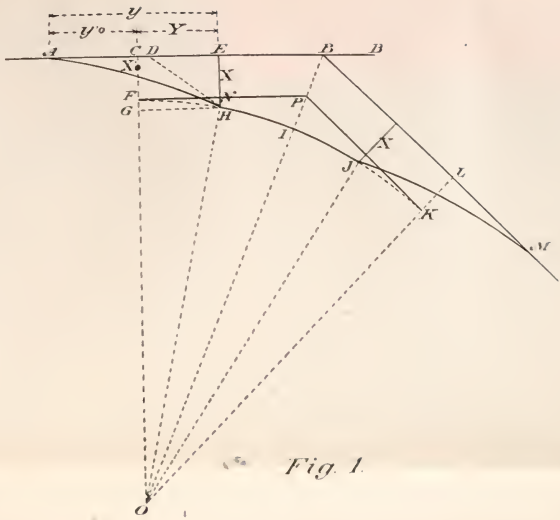


Fig. 1.

Line D-H is tangent to curve and spiral.

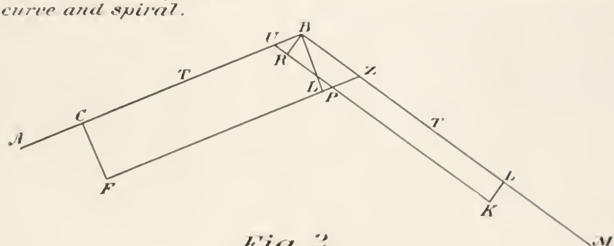


Fig. 2.

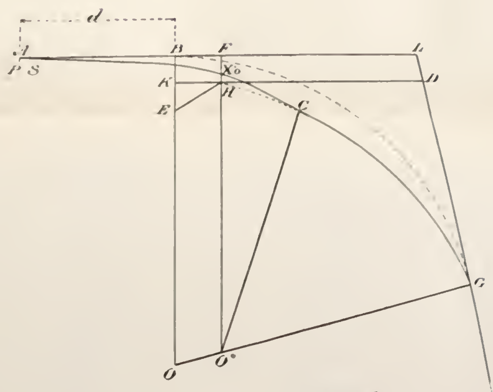


Fig. 3.

zero reading then gave line of the tangent at H. and the circular arc was then located as usual.

The spiral JM was located in the same way as the spiral at the other end, AH. In this connection I wish to say that our tables are arranged for 18, 24, 30, 36, 48 and 60 foot spirals.

I think there is already given enough formulas for the construction of tables necessary for use in locating easement curves in realignment work, and the formulas necessary for computing the easements are given without going into details. The transit work and the calculations are about as ordinarily performed in locating circular arcs.

As has been stated, the work of locating the spiral between the parts of compound curves is better performed by trial than by computation. In realignment work, the arcs of compound curves are necessarily located by trial. It is just as easy to locate spiral between compound curves in the same way.

In introducing a compound between a 2-degree and 6-degree curve for a 60-foot spiral, it would require 240 feet of spiral curve. Referring to the tables for deflections of a 60-foot spiral for 30-foot cords, if the spiral curve is located from the 6-degree curve the deflections will be the difference between the deflections for a 6-degree curve and that of a 60-foot spiral. If the spiral is located from the 2-degree curve, then the deflections are the sum of the deflections for a 2-degree curve and that of a 60-foot spiral.

From the 6-degree curve total deflections down to a 2-degree curve will be as follows:

Distance.	Deflections for an 8-deg. Curve.		Deflections for a 60-ft. Spiral. d.		Total Deflections.	Deg. of Curvature.
0+30	0—54	—	0— 1.5	=	0—52.5	5 deg. 30 min.
+60	1—48	—	0— 6.0	=	1—42	5 " 00 "
+90	2—42	—	0—13.5	=	2—28.5	4 " 30 "
1—20	3—36	—	0—24	=	2—12	4 " 00 "
1—50	4—30	—	0-37.5	=	3—52.5	3 " 30 "
1—80	5—24	—	0—54	=	4—20	3 " 00 "
2—10	6—18	—	1—13.5	=	5— 4.5	2 " 30 "
2—40	7—12	—	1—36	=	5—36	2 " 00 "

Back deflections to turn on tangent 7 deg. —12 min. —2 deg. =7 deg. —12—3—12=4 deg. 00 min.

If the spiral is located from a 2-degree curve running up to 6-degree the deflections are as follows:

Distance.	Deflections of a 2-deg. Curve.		Deflections of a 60-ft. Spiral.		Total Deflections.	Deg. of Curvature.
30	0—18	+	0— 1.5	=	0—19.5	2 deg. 30 min.
60	0—36	+	0— 6.0	=	0—42.0	3 " 00 "
90	0—54	+	0—13.5	=	1—-7.5	3 " 30 "
1—20	1—12	+	0—24.0	=	1—37.0	4 " 00 "
1—50	1—30	+	0—37.5	=	2— 7.5	4 " 30 "
1—80	1—48	+	0—54.0	=	2—42	5 " 00 "
2—10	2— 6	+	1—13.5	=	3—19.5	5 " 30 "
2—40	2—24	+	1—36	=	4—00	6 " 00 "

Back deflections to turn on tangent =2+24+3—12=5 deg. 36 min. 3 deg.—12=2 deg.

TABLE No. 1. 60-FOOT SPIRAL.

$N=1,\ X_0=\frac{1}{4}X,\ d=\frac{1}{3}\ i.$

D.		L.	X.	Y.	Y_0.	d.		i.	
0	10	10	.00	10.	5.00	0	0.2	0	0.6
	20	20	.00	20.	10.00	0	0.7	0	2.1
	30	30	.01	30.	15.00	0	1.5	0	4.5
	40	40	.03	40.	20.00	0	2.7	0	8.1
	50	50	.06	50.	25.00	0	4.2	0	12.6
1	00	60	.10	60.	30.00	0	6.0	0	18.0
	10	70	.17	70.	35.00	0	8.2	0	24.6
	20	80	.25	80.	40.00	0	10.7	0	32.1
	30	90	.35	90.	45.00	0	13.5	0	40.5
	40	100	.48	100.	50.00	0	16.7	0	50.1
	50	110	.66	110.	55.00	0	20.2	1	0.6
2	00	120	.84	120.	60.00	0	24.0	1	12.0
	10	130	1.06	129.99	65.00	0	28.2	1	24.5
	20	140	1.33	139.99	70.00	0	32.7	1	38.0
	30	150	1.64	149.98	75.00	0	37.5	1	52.5
	40	160	1.99	159.98	80.00	0	42.7	2°	8.0
	50	170	2.38	169.97	85.00	0	48.2	2	24.5
3	00	180	2.83	179.96	90.00	0	54.0	2	42.0
	10	190	3.32	189.95	95.00	1	0.1	3°	00.5
	20	200	3.88	199.93	100.00	1	6.7	3	20.1
	30	210	4.49	209.91	104.99	1	13.5	3	40.5
	40	220	5.16	219.89	109.98	1	20.7	4	02.0
	50	230	5.90	229.86	114.98	1	28.2	4	24.5
4	00	240	6.70	239.83	119.97	1	36.0	4	48.0
	10	250	7.57	249.79	124.97	1	44.2	5	12.5
	20	260	8.51	259.75	129.96	1	52.7	5	38.0
	30	270	9.53	269.70	134.95	2	1.5	6	4.5
	40	280	10.63	279.64	139.95	2	10.7	6	32.0
	50	290	11.81	289.57	144.93	2	20.1	7	00.5
5	00	300	13.07	299.49	149.91	2	30.0	7	30.0
	10	310	14.42	309.40	154.91	2	40.2	8	0.5
	20	320	15.86	319.29	159.89	2	50.1	8	32.0
	30	330	17.34	329.17	164.86	3	1.5	9	4.5
	40	340	19.02	339.04	169.85	3	12.7	9	38.0
	50	350	20.74	348.89	174.82	3	24.2	10	12.5
6	00	360	22.56	358.72	179.79	3	36.0	10	48.0
	10	370	24.49	368.54	184.76	3	48.2	11	24.5
	20	380	26.52	378.33	189.72	4	0.7	12	2.1
	30	390	28.66	388.09	194.68	4	13.5	12	40.5
	40	400	30.91	397.84	199.64	4	26.7	13	2.0
	50	410	33.27	407.60	204.60	4	40.3	14	00.9
7	00	420	35.74	417.35	209.55	4	54.0	14	42.0
	10	430	38.32	427.07	214.54	5	08.5	15	25.5
	20	440	41.03	436.82	219.50	5	22.8	16	8.4
	30	450	43.84	446.54	224.45	5	37.6	16	52.8
	40	460	46.78	456.25	229.40	5	52.8	17	38.4
	50	470	49.84	465.96	234.34	6	08.2	18	24.6
8	00	480	53.01	474.65	239.28	6	24.0	19	12.0

TABLE No. 2. 30-FOOT SPIRAL.

$n = \frac{1}{2}$.

D.		L.	X.	Y.	Y_0.	d.		i.	
0	20	10	.00	10.00	5.00	0	0.3	0	1.0
	40	20	.01	20.00	10.00		1.3		4 0
1	00	30	.03	30.00	15.00	0	3.0	0	9.0
	20	40	.06	40.00	20.00		5.3		16.0
	40	50	.12	50.00	25.00		8.3		25.0
2	00	60	.21	60.00	30.00	0	12.0	0	36 0
	20	70	.33	70.00	35.98		16.3		49.0
	40	80	.50	80.00	39.98		21.3	1	4.0
3	00	90	.73	90.00	44.98	0	27.0	1	21 0
	20	100	.97	99 99	49.97		33.3		40.0
	40	110	1.29	109.99	54.97		40.3	2	1.0
4	00	120	1.68	119.98	59.97	0	48.0	2	24.0
	20	130	2.14	129.97	64.96		56.3		49.0
	40	140	2.66	139.95	69.96	1	5.3	3	16 0
5	00	150	3.27	149.93	74.95	1	15.0	3	45.0
	20	160	3.97	159.91	79.94		25.3	4	16.0
	40	170	4.77	169.88	84.94		36.3	4	49.0
6	00	180	5.65	179.84	89.93	1	48.0	5	24.0
	20	190	6.64	189.79	94.91	2	0.3	6	1.0
	40	200	7.75	199.73	99.89	2	13.3	6	40.0
7	00	210	8.96	209.65	104.86	2	27.0	7	21.0
	20	220	10.30	219.56	108.89	2	41.3	8	4.0
	40	230	11.77	229.45	114.82	2	56.3	8	49.0
8	00	240	13.38	239.33	119.79	3	12.0	9	36.0

TABLE No. 3. 18-FOOT SPIRAL.

$n = \frac{3}{10}$

D.		L.	X.	Y.	Y_0.	d.		i.	
0	20	6	.00	6.00	3.00		0.2		0.6
	40	12	.00	12.00	6.00		0.8		2.4
1	00	18	.01	18.00	9.00	0	1.8	0	5.4
	20	24	.02	24.00	12.00		3.2		9.6
	40	30	.04	30.00	15.00		5.0		15.0
2	00	36	.08	36.00	18.00	0	7.2	0	21.6
	20	42	.12	42.00	21.00		9.8		29.4
	40	48	.18	48.00	24.00		12.1		36.1
3	00	54	.25	54.00	27.00	0	16.2	0	48.6
	20	60	.35	60.00	30.00		20.0	1	00 0
	40	66	.46	66.00	33.00		24.2		24.6
4	00	72	.60	72.00	36.00	0	28.8	1	26.4
	20	78	.77	79.99	38.99		33.8		41 4
	40	84	.91	83.99	41.99		39.3		57.7
5	00	90	1.18	89.99	44.99	0	45.	2	15.0
	20	96	.43	95.98	47.98		51.2		35.6
	40	102	.71	101.97	50.97		57.8		53 4
6	00	108	2.04	107.97	53.97	1	4.8	3	14.4
	20	114	.39	113.95	56.96		12.2		36.6
	40	120	.79	119.94	59.95		20.0	4	00.0
7	00	126	3.23	125.93	62.94	1	28.2	4	24 6
	20	132	.72	131.91	65.93		36.8		50.4
	40	138	4.25	137.88	68.92		45.8	5	17.4
8	00	144	4.83	143.85	71.90	1	55.2	5	45.6

CURVE ELEVATION.

By W. M. Camp.

In entering upon an investigation of the much-discussed subject of curve elevation the Committee proceeded on the ground that the question is necessarily complicated by widely prevailing abnormal conditions. It was therefore the aim of the Committee to report practice somewhat extensively, with only such generalizations as could be clearly deduced from the data submitted. In this undertaking the Committee was favored with 74 replies to a circular of inquiry bearing upon those particular phases of the subject which it was desired to investigate at this time. Nearly all of these replies were exceptionally full and carefully prepared as to definite points of information asked. The circular was generally distributed among maintenance-of-way officials, and the replies cover 60 different lines of railway or railway systems, 46 of which are prominent roads of the country, operating through passenger trains. So far as could be ascertained from the replies, 35 represent roads on which the principal traffic is freight, 11 represent roads on which the principal business is passenger traffic, and 19 represent roads handling a mixed traffic. The remaining 9 replies omitted mention of the class of traffic.

A principal object of the investigation was to ascertain to what extent the rules for curve elevation in force on various roads were derived from purely theoretical considerations. Out of the 54 replies bearing on this point, 21 indicate that the formula for centrifugal force was used in deriving a general rule, but in nearly every case the rule so derived was modified to adapt it to practice. Thirty-three replies indicate that the rule in force was determined by trial, without mathematical consideration of the mechanical principles involved. Our information is therefore conclusive to the effect that in general practice the question of curve elevation is finally settled by experiment, to whatever extent the basis of the rule may rest upon theoretical calculation. Not less than 6 replies, covering in each case a large railway system, having a well organized engineering department, state that no rule or table for curve elevation is established, the matter being left to the judgment of the roadmaster or engineer in charge of each division.

The rule most largely in force (24 replies) for mixed traffic on level track is to elevate the outer rail 1 inch per degree of curve, up to a maximum of 6 inches of superelevation. In the instance of 10 replies the rate for similar conditions is ¾ inch per degree. For single-track mountain roads, where heavy grades prevail, a rate as low as ½ inch or ⅝ inch per degree of curve is extensively used, the maximum elevation in such cases being usually 3 to 5 inches. On roads where the conditions are such that the freight traffic may be disregarded, the rate of elevation for the passenger traffic varies all the way from 1¼ to 2 inches, and even 2½ inches, per degree, the preference seeming to lie equally with the 1¼ and 1½ inch rates. On several roads, however, it is the practice to introduce a constant additional to a rate varying uniformly with the curvature, as, for instance, in the practice of the New York Central

& Hudson River Railroad, where the general rule for the elevation of main passenger tracks of 1 degree and over is 1 inch per degree plus 1½ inches, the maximum elevation being 6½ inches. On some other roads the rate is 1 inch per degree plus 1 inch. This arrangement provides a proportionally large elevation for the smaller degrees of curvature, which seems to be a principle extensively followed. The Philadelphia & Reading Railway makes use of a convenient rule, experimentally derived with the idea of maintaining a proper relation of curvature to speed, by which the superelevation is taken as the middle ordinate of a chord equal in length to the distance run by the express trains per second, the maximum elevation being fixed at 8 inches. The fast passenger service is given the greater consideration, notwithstanding that the principal traffic is coal and heavy freight.

Respecting the matter of maximum elevation preference seems to be decidedly in favor of 6 inches. On this question the Committee had 41 replies, 5 of which reported 5 inches, 1 reported 5½ inches, 23 reported 6 inches, 1 reported 6½ inches, 6 reported 7 inches, 1 reported 7½ inches, and 4 reported 8 inches. Practice in this respect does not seem to admit of ready generalization as to the class of traffic, for several roads operating express trains on fast schedule stop at a maximum elevation of 5 or 6 inches.

In general, two ideas are followed in elevating curves, one being to adopt rules covering typical conditions affecting the speed and then apply such elevation as conforms to the rule; and the other is to estimate the elevation first applied, according to knowledge of the speed and traffic, and then observe carefully the riding of the cars and if necessary adjust the elevation until the cars ride satisfactorily. The latter method is the more common in practice. The speed used as the basis of trial or calculation for fast traffic is 55 to 60 miles per hour, more frequently 60 miles; for mixed traffic the speed is 30 to 50 miles per hour, more frequently 45 or 50 miles. It is seldom the case that the application of a rule for curve elevation is made hard and fast, variations being introduced to suit local conditions of grades and speed. Thus, for example, the elevation of curves on summits is usually less, and that of curves in sags usually more, than the customary elevation in vogue for curves of the same degree on level road. In the vicinity of stations, watertanks, unprotected grade crossings, draw bridges, etc., where stops are made or speed habitually reduced, there is also a decrease in the elevation. In some cases, also, where turnouts occur on curves the rule is not followed, the speed of trains being reduced at such places.

In the great majority of cases the rate of elevation determined upon is a compromise of the requirements of slow-speed freight trains and the speed of passenger trains. Thus, out of the 74 replies only 33 report giving the passenger traffic the preference, and in but very few cases is it given the sole consideration, in elevating curves. On the other hand, instances are still less numerous where the freight traffic is given the sole consideration, there being only four replies to indicate such practice.

The testimony of the replies as to the ill effects from heavy, slow-speed freight trains on curves fully elevated for fast passenger traffic

is decisive and in numerous instances emphatic. Out of 59 replies bearing on this question, 48 mention one or more detrimental effects to track by reason of the disparity of the elevation as applying to the two classes of traffic. Nearly all report excessive wear to the inner rail, the canting of that rail, and abnormal cutting of the ties. Other objectionable results are the tendency of the track to constantly increase its elevation, owing to the disproportion of weight bearing upon the inner side of the curve, and the consequent displacement of the track in line and surface; the bending of tie-plates, as well as the creation of a necessity for the use of tie-plates. On the Philadelphia & Reading Railway (where the maximum elevation is 8 inches) the tendency of the inner rail to cant under the slow-speed trains is overcome "by the use of heavy tie-plates," but, according to the report, "they are not found to be necessary under the outer rail." There is also a remarkable tendency to derailment or capsizing of the cars, due to the tilting effect, which relieves the outer wheels of an undue share of the load, as the following quotations from the replies to the circular will show:

"On new roads this excessive elevation for slow, heavy freights develops low places on the inside rail, and cars already leaning heavily to that side swing over and take so much weight off the outside rail that new wheels mount that rail. I had frequent instances of this last year on a new division of the —— railway."

"There is a tendency for the load to raise the outer wheels and cause them to jump the track at bad joints."

"The principal traffic is freight, and on account of the sharp curvature the elevation is necessarily limited, on that account. If the elevation on our curves from 16 to 20 degrees is over 6 inches, and the speed of freight trains from any cause is reduced to from 4 to 6 miles per hour, derailments frequently occur."

"Excessive elevation makes the movement of slow and heavy trains difficult, reduces the tonnage rating of power, makes track maintenance costly, and the movement of top-heavy lading dangerous."

"It may sometimes be necessary to stop on a sharp curve, and if elevated for exceedingly high speed it might cause trouble. I have heard of a train stopping on a curve with some plate girders extending over three flat cars, and the girders fell over on account of elevation."

"The effect of slow-speed freight trains on track fully elevated for fast speed is very damaging to the track, both as to line and surface, sometimes causing derailment of freight cars. The excessive elevation also reduces the hauling capacity of freight engines on up grade."

"It is difficult after elevating curves for fastest passenger trains to keep track in line on curves where heavy, slow-speed freight trains are run."

Numerous replies also complain of increased train resistance from excessive elevation for slow-speed trains. We have the statement of the chief engineer of a mountain road to the following effect: "On our main line we elevate for a speed of 33 miles per hour, but on the —— mountain grade our maximum elevation is only 3 inches, and we find that freight trains do better."

On the great majority of roads it is the practice in elevating curves to place the inner rail at grade and obtain all of the superelevation by raising the outer rail. While some admit that this arrangement effects

a slight lifting of the entire grade throughout the curve, with a perceptible slight "lifting sensation," on entering or leaving the curve, there nevertheless seems to be no serious objection. Out of 74 replies to this question 56 report placing the inner rail at grade, 16 report that they obtain half of the superelevation by elevating the outer rail and the other half by depressing the inner rail, while only 2 report placing the outer rail at grade.

The most frequent rate of running out elevation at the ends of curves is 1 inch in 60 feet, such practice being reported by 22 replies, while 14 replies indicate a rate of 1 inch in 50 feet, 4 replies a rate of 1 inch in 40 feet, and 9 replies a rate of 1 inch in 30 feet. Scattering replies indicate rates varying all the way from 1 inch in 35 feet to 1 inch in 120 feet. Touching the matter of running out curve elevation it is clear that wherever fast speed assumes importance practice is fast changing in the direction of spiraling the ends of curves, thus making it possible to elevate with the curvature and maintain tangents level transversely their whole length. Out of 74 replies 57 report some form of easement curve. These curves take a variety of names as known to practice, mention being made of the Searles, Holbrook, Crandall, Talbot and Torrey spirals, the cubic parabola, tapering curves, and other transition curves not designated by particular names. Although these curves differ but little in geometrical form, the name being applied principally to the manner of running out the curve, the preference seems to be decidedly with the Searles spiral, the Holbrook spiral coming next in order of preference, these two being mentioned more frequently than all others combined. In most cases the length of the easement is variable, according to the degree of the main curve or the height of the elevation, but in a few instances standard lengths of 100, 180, 200 and 300 feet are mentioned. In nearly every case it is the practice to run out the elevation with the easement, but some exceptions occur. The practice on the Michigan Central Railroad, as described by Chief Engineer A. Torrey, is as follows:

"It is our practice to give the transverse inclination, which is required for the first chord of the easement, to the tangents at the tangent points. I presume this is run out in half a rail length. It is our practice to give the full elevation for the curve, if it is a simple curve with easements at each end, at that point of the chord of the last piece of easement which is remote from the central curve. We have quite a lot of curves which in the original location were made up of two or more simple curves. It is our practice to join these simple curves, where they differ by more than 30 minutes in each 100 feet of curvature, by an easement similar in type to the easement at the junction of the tangents, but beginning at one end with the chord of slightly less radius than the chord it unites, and ending the easement with a chord of slightly greater radius than the chord it unites with. This naturally makes a rather complex system of superelevation in such instances, but is certainly worth all the trouble it involves to the engineer who has the location of this interior easement to stake out, and of the trackman who has to determine just where the changes in superelevation are to be made."

On the St. Louis & San Francisco Railroad the form of easement in use is a series of compound curves of 25-foot chords. The run-off starts

with full elevation at the end of the main curve and extends onto the tangent 25 feet beyond the point of easement. The purpose of this arrangement is to obtain the full elevation for each chord of the easement curve as it is reached. While it is admitted that this method of running out the elevation is wrong in theory it is claimed that it produces better results than the usual method of elevating spirals.

Concerning this method as tried on another road the engineer states as follows: "Have tried commencing elevation half a chord length before reaching beginning of easement and obtaining full elevation the same distance before reaching P. C. regular curve, but could feel no difference in the riding of the cars, so I returned to the regular practice as being easier for section men to follow."

Five replies to the circular express a preference for curving the rails of spirals to correspond to the curvature of the spiral at the position of the rail. More specifically one informant replies as follows: "The rails for the easement should be curved for that portion of the same whose curvature exceeds that limit for which the rails are curved in general practice. The rails should be curved to the middle ordinate that will fit the degree of curve at the point where the middle of the rail will lie when in position. The ends, when coupled together, will offset each other's strain and lie very nicely in the track to the position required."

On the question of elevating curved track in yards and sidings, 41 replies report that no elevation is practiced, while 25 replies report a reduced rate of elevation in such cases, 2 inches seeming to be a favorite maximum elevation. In a few instances the rate for sidings is half that for main line. In a single instance a rate of 1-16 to ⅛ inch per degree was mentioned.

It is important to recognize that the flange pressure of wheels against the outer rail of curves may be due to two forces, namely, the reaction of the wheel which ensues from being turned from a straight course, and centrifugal force due to speed. With proper elevation for the speed the centrifugal force may be counteracted, but the lateral pressure due to the tendency of the wheels to run in a straight line is always present. It is therefore impossible by any known arrangement to prevent flange pressure of wheels against the outer rail of curves. With a view to show that the elevation of curves does not overcome all objectionable features or elements of danger in curved track the Committee sought to find the collective opinion of maintenance-of-way officials by including in its circular of inquiry the following question:

"Do you consider properly elevated curves as safe as tangents, and, if not, in what respect do you think danger is to be looked for?"

To this inquiry there were 68 responses, 45 in the negative and 23 in the affirmative, the latter, however, in many instances, being qualified to include only moderate or very easy curvature. In the main the chief source of danger on curved track maintained in good alignment and surface and elevated according to approved standards is to be expected from defects in rolling stock. However, there is much opinion in support of

the belief that certain tendencies to danger are inherent with the track itself, by reason of the curvature, and it can certainly be established that the development of certain defects to be looked for in curved track is promoted with increase in the curvature, independently of the elevation of the same. In support of these views we think well to submit a few typical answers to our circular of inquiry:

"I consider properly elevated curves up to 3 degrees as safe as tangents, but curves of 4 degrees and more are harder on rails, ties and rolling stock."

"Do not think curves as safe as tangents. A wheel with broken flange would run miles on straight line, but would hardly round a sharp curve."

"I do not think it possible to construct a curve of more than 1 degree that will be as safe as straight line, the principal danger being from defective rolling stock and improperly loaded cars. But I do think that a curve of 1 degree or less is probably just as safe, or safer, than straight line."

"No. Because the binding of cars on side bearings and defects in track, especially in connection with outer rail of curve, which, on straight track would cause no trouble, do cause derailments on curves."

"I do not consider properly elevated curves as safe as tangents. No matter how carefully a curve is elevated, the resistance of train to change of direction still remains. We must overcome this by stronger and more perfect track than is required on tangent. The danger to be looked for is in defective rails, soft wood or poor ties, low joints, etc."

"I do not consider curves properly elevated as safe as tangents, and the greater degree of curvature, the greater the element of danger. There is a side strain on curves not found on tangents, which it is necessary to overcome before it is as safe as tangent. Danger, I think, will be in track spreading; more danger from broken rails and from defective trucks and flanges."

"Danger from curves is due mainly to worn rails, causing the wheel flanges to strike the splices, and from failure in some cases to properly adjust the gauge to the actual wheel base of the engines. Also, of course, to defective vertical and horizontal support of rails and irregular alignment."

"Properly elevated curves are as safe against danger from centrifugal force as tangents, but other reasons make them unsafe, the principal difficulty coming from the fact that the distance to be traveled on the outer rail is greater than that on the inner rail, and the wheels have to slip over towards the low rail. On mountain grades, where the rail has been sanded by a preceding train, we find a great deal of difficulty from the tendency of this sand to prevent the necessary slipping, and consequently the forward truck wheel climbs over the outer rail. The tendency to do this does not at all depend on the speed of the train, as it occurs quite as often at low as at high speeds."

"I do not consider properly elevated curves, or any curves, as safe as tangents. A derailment may be caused by much slighter derangements, or concurrence of a less number of abnormal conditions on a curve than on a tangent. I do not think, however, that a curve in the best possible condition is to be considered directly responsible for such an accident as above supposed, but that it is a condition to which it is not too difficult to add others, so that the combination leads to accident."

"I do not think any curve, however light, is as safe as tangent, and I believe the danger lies in derailment caused by insufficient bracing of outer rail, and also from lurching of improperly loaded cars while in

motion across that portion of the tangent adjacent to the curve, upon which is made the run-off of the curve."

"I do not consider any curved track as secure from causing derailment as straight track. There is always some lateral pressure on the rails of curved track, and it is generally greater than the same kind of pressure on straight track. With this pressure always at hand, and in some cases very severe on the outer rail, any fault of the equipment passing over track, which is even in perfect condition, may put an obstacle on the track, and that obstacle, joined with the lateral pressure, may be such that a derailment may occur at a curve which would not be at all likely to occur on tangent. The flanged wheels of engines and the leading trucks of engines are variously arranged, and in some arrangements bring an undue strain on track, and wheel flanges, which may be forever innocuous on tangents, under the right conditions of wear of tire, flange and rail, may be very hazardous in the passage of a curve."

"I do not consider properly elevated curves as safe as tangents, for the reason that locomotives are not always properly counterbalanced for the speed they are required to make."

"In practice it is much more difficult to maintain curved track in as safe or in as good riding condition as tangents, this especially on roads handling mixed traffic. Heavy, slow trains disturb and strain the curves more than the tangents. As a rule, the curves are not as safe as tangents, because they cannot be maintained to proper elevation for all traffic, while tangents are level."

A question which has an important bearing upon the elevation of curves is the limitation of speed in relation to curvature. While it is well understood that no hard and fast lines stand in the way of the physical possibilities of speed on such curves as are in common service, there is nevertheless a decided and deeply-founded belief on the part of maintenance-of-way engineers that at certain limits of curvature, which fall within a maximum to be found on almost every road, the speed of trains should be restricted to reasonable limits. The basis of this opinion is that by reason of mixed traffic and liability to reduction in speed with even the fastest traffic, the ideal elevation of curves cannot be practiced. Assuming maximum elevation at 6, or even 8, inches, any of the customary rules for the fastest traffic cannot be followed beyond a comparatively low limit of curvature. In the circular of inquiry it was the aim of the Committee to draw out some expression of opinion on this matter, and although several did not wish to commit themselves to positive answers, the circular nevertheless elicited numerous responses. The question asked read as follows:

"At what limit of curvature do you think speed of 60 miles per hour should not be exceeded? State any reason you may have for this opinion."

Out of the 58 replies received, 1 placed the limit at 1 degree, 2 placed it at 2 degrees, 15 placed it at 3 degrees, 3 placed it at 3½ degrees, 21 placed it at 4 degrees, 1 placed it at 4½ degrees, 4 placed it at 5 degrees, 1 placed it at 5½ degrees and 10 placed it at 6 degrees. No reply favored a higher limit that 6 degrees. The weight of opinions is thus favorable to 4 degrees or less as the safe limit of curvature for speed exceeding 60 miles per hour. The reasons for these opinions are best explained by direct quotations from a few of the replies, as follows:

"Three-degree curve. It is not advisable, for practical reasons, to have a greater elevation of rail than 8 inches, and for 60 miles per hour this is about the superelevation for a 3-degree curve."

"From observation, I would say that speed of 60 miles per hour should not be exceeded on curves of over 3 degrees. The only reason I have for this is that I have gone around curves of 3 degrees at that rate of speed and felt very comfortable. In one or two instances I have gone at a higher rate of speed, and felt decidedly uncomfortable. This was due to the fact that the train was bearing too heavily, in my judgment, against the outside rail."

"I think 3 degrees should be the limit, because proper elevation cannot be given any sharper curves on account of slower trains. The elevation for a 3-degree curve for 60 miles per hour would be 8 inches, and I do not think this should be exceeded."

"I think a 4-degree curve, with 5-inch elevation, the limit of a speed of 60 miles per hour, and for curves sharper than that the speed should be reduced 5 miles per hour for each degree above the 4 degrees, i. e., a 6-degree curve should be limited to 50 miles per hour and a 10-degree curve to 30 miles per hour, and that is the rate of speed these curves will carry without the cars tilting outward to such an extent as to be appreciable to a passenger."

Four degrees. No particular reason, only I think there should be a limit to speed around curves. Have ridden engines around 4-degree curves at 60 miles per hour, and think it fast enough."

"Four-degree curve. We are now throwing out a curve on our —— division, known as "Dead Man's" curve. It is a 10½-degree curve, at the foot of a long 1½ per cent grade, and trains run fast down this hill. We had a special car thrown off a passenger train a year or two ago, and several prominent people were shaken up pretty badly. The track has been kept in good condition, but we have had several derailments there, although I do not think the trains ever ran over it as fast as 60 miles per hour. We are replacing it with a 4½-degree curve."

"Four degrees. I have not ridden over any track at a rate of 60 miles in which there were 3, 4 and 5 degree curves without being very conscious of them. My idea is that a person riding should not have his attention drawn to the track by reason of its inequalities, or that outward thrust experienced in going round a curve too fast."

"Do not see any reason why speed of 60 miles per hour should not be made on curves of 5 or 6 degrees if the track be properly elevated for that rate. On single-track roads the difficulty is found in adjusting the elevation to fit 60 miles downhill and 10 miles uphill."

"Four degrees is, I think, the limit of curvature over which trains should run at 60 miles per hour, especially if the track is intended to serve for both passenger and freight traffic. If for passenger traffic alone, I should say that curvature of 5 degrees could be maintained, so as to permit trains to run at a rate of 60 miles per hour. My reason for thinking the above-mentioned degrees of curvature maximum permissible in good practice for the rates of speed named, is that the elevation becomes so great that if trains should run as they at times necessarily do run, at considerably lower rate of speed, the track is liable to be thrown out of adjustment and there is possible the liability to derailment on account of the excessive bearing of wheels on the low rail, or in the overtipping of freight cars not symmetrically loaded in case they should be bumped or jerked in slow running or in stopping and starting."

"I think that a speed of 60 miles an hour should not be exceeded on a curve of over 4 degrees, on account of the danger of spreading track or the outer wheel flange climbing the rail at bad joints."

"I would limit the curvature at 6 degrees where the speed is 60 miles per hour. If the curve exceeds 6 degrees I would reduce the speed of trains."

"A speed of 60 miles per hour should not be exceeded on a 6-degree curve, as the required elevation would be too great."

"The —— and other mountain roads have a large number of 6-degree curves over which trains often make 60 miles per hour, but to go beyond this would increase the danger from broken axles or flanges. This may be illustrated as follows: Elevation required for 6-degree curve for slow freight, dragging uphill at 15 miles per hour, is 1 inch. Same curve for fast passenger coming down grade 60 miles per hour requires 15 inches. The compromise elevation usually given is 6 inches. Excess of elevation for freight, 5 inches; deficiency in elevation for passenger, 9 inches. While this 5-inch excess elevation for the slow train is almost great enough to throw such a proportion of the weight on inner rail that the friction of the tread of inner wheel is liable to overcome friction of flange on outer rail and thus derail the train, the 9-inch deficiency of elevation in this same curve for the fast train throws such a large proportion of its weight laterally against the outside rail that the danger point cannot be far off."

The information reviewed by the Committee in making this report seems to support the following recommendations, which we offer for the consideration of the Association, hoping that any points found to be in dispute may be accorded the benefit of a full discussion:

1. The range of the application of the usual formula based on centrifugal force ($g\ V^2 \div 32.2\ R$) is so limited that it is practically of no value for the calculation of general rules for curve elevation. The logical and only practicable method of determining rules for curve elevation to meet the conditions of practice is by trial, with typical examples of curvature and speed, adjusting the elevation until the trains ride satisfactorily.

2. Adopting the method of trial, any formal consideration of the speed of trains is immaterial, since if the trains ride satisfactorily on the elevation determined by this method the object sought is fully accomplished.

3. The following approximate rules cover typical classifications of traffic sufficiently well to be safely followed until trial under the local conditions may determine necessary modifications:

(a) For heavy freight traffic, elevate at the rate of ¾ inch per degree, up to a maximum of 5 inches.

(b) For mixed traffic, elevate at the rate of 1 inch per degree, up to a maximum of 6 inches.

(c) For fast passenger traffic, where the freight traffic may be disregarded, elevate at the rate of 1 inch per degree, plus 1 inch, up to a

(d) If the curvature be such that more than 6 inches would be required by following the rule in any of the above cases, the speed should be reduced rather than exceed the adopted maximum elevation.

4. The inner rail should be placed at grade. While it is possible to demonstrate some advantages for placing the track at grade on center line, the depression of the lower rail introduces some difficulties into the work of maintaining proper surface at the ends of the curves.

5. The only satisfactory method of running out curve elevation is in connection with the use of easement curves. The track at the point of easement should be level transversely, and the elevation for the curve should be developed with the easement, reaching full elevation at the end of the easement or beginning of the main curvature. If the conditions of location will permit, the length of the easement should be such that the elevation may be run out at the rate of 1 inch per 30 to 60 feet of easement.

6. Speed as high as 60 miles per hour should not be made on curves sharper than 4 degrees.

INSPECTION OF TRACK.

By S. B. Fisher.

There are reports from only 23 roads. While the reports are not as numerous as we would like, nor as full and specific in some cases as we would desire, they come from all parts of the country, excepting from the Pacific Coast. They come from long roads and short roads, from roads where traffic is thick and heavy, where it is medium and where it is light. They apparently give a fair summary of the current practice between the Atlantic Ocean and the Pacific Slope.

Track Walking—When Resorted To.—With three-fourths of the roads this is required daily. A very few roads require detailed special inspectors to patrol the track constantly. One road in the Northeast requires in its regular routine a semi-daily inspection of track during the winter months. Very few roads, and these with thin traffic, require inspection only every two days. Several require inspection on six days, omitting Sunday. The great majority of roads, however, require a daily inspection, this inspection to be made by the section foreman and his gang over the portion of the road which they traverse going to work, and by a man detailed to patrol the portion of road which they do not go over on that day.

A number of roads with medium traffic do not require regular track walking in fair weather, but all require it during and after storms. Many roads require track walking during storms at night. All roads which run along the foot of bluffs, so far as heard from, require special track walking during thaws and rains.

Track Walking—Particular Requirements Of.—Track walkers are required to inspect, first, and most of all, the track, and, secondly, the right-of-way, fences, etc.

The track walker is required to have a spike maul, wrench and train signals, and any other special tool or appliance required. He is required to look for broken rails and ties, to look for spikes loosened or broken, to note especially the joints, to replace bolts when out of joints, to tighten loose bolts, to replace and secure shims and to clean public road crossings. He is required to remedy small washings of roadbed and to drain small puddles of water in the ditches. He is required to put stock off the right-of-way, when found, and to repair the fence; in short, to fix up anything that is amiss, when he can do it without much loss of time

or labor, and when the trouble is at all serious to report to section boss or other agent of the company.

Special Inspection of Switches, Frogs, Crossings, Derailing Points, Interlocking Plants, Etc.—Requirements.—All roads require special inspection of frogs, switches and crossings; most roads require it daily in the morning. Several roads require weekly inspection by section foreman. Many have periodical inspection by supervisor, superintendent or engineer of maintenance-of-way. Only one or two roads report definite standards to guide these inspections. Nearly all roads seem to have regular, or irregular, general inspection of some kind for frogs and switches in addition to inspection by section forces.

The majority of roads do not appear to have derailing points and interlocking plants enough to say what they do about them. The ones that do only require a casual inspection from track walkers or section force, requiring them to remedy trivial or rough defects, and having a skilled mechanic or special inspector to attend to them.

Inspection of Bridges, Trestles, Culverts, Etc., by Trackmen.—All roads require some kind of inspection of bridges, trestles and culverts by trackmen. Some require it weekly and some daily. Nearly all roads require trackmen to keep culverts free from obstructions, and to keep inflammable material of any and every kind away from wooden structures. All roads require trackmen to either make right or report any damage or danger to bridge and trestles during or on account of storms, floods, thaws or accidents from any cause. Most roads do not rely much on section men in maintenance of bridges and trestles, but trust to their bridgemen.

CROSSINGS.

By W. H. Kimball.

A, Foundations and Drainage. B, Types.

The following is the practice on the roads named below:

Buffalo & Susquehanna Railroad.—Square timbers, 12x16 inches, on gravel. Natural Drainage. "If crossing is less than 9 or 10 degrees, movable points should be used."

Chicago, Milwaukee & St. Paul.—A, gravel and stone ballast. B, reinforced.

Chicago & North-Western Railway.—B, for large angles and heavy traffic. Easer rails entire length. For light angles only near the angles. For light traffic not at all. Framed timber not used. Ties for all angles. Wrought-iron fillers. Filled and bolted crossings. No plates. One-inch bolts for heavy rail.

Chicago, Rock Island & Pacific Railway.—B, bolted crossing. Wrought fillers. Easer rail. Five-eighths-inch plate under each angle to get better bearing on ties and act as a binder. Ties usually set at right angles to line having greatest traffic. For angles between 50 and 90 degrees, framed oak timbers, 8x14 inches. Under angles of 50 degrees, ties, bisecting crossing angles, 7x9-inch oak. A, crushed rock and tile when necessary.

Denver & Rio Grande Railroad.—A, cinders and decomposed granite. B, home-made.

Georgia Railroad.—A, crushed stone. Drainage obtained as in other parts of track. B, various.

Houston & Texas Central Railway.—A, 12-inch ballast. 7x10-inch ties. B, bolted with guard rails.

Illinois Central Railroad.—B, over 60 degrees. Easer rails entire length. Prefer ties to framed timbers, even on 90-degree crossing angles. Use bolted crossings and do not consider it any advantage to use plates. Wrought-iron or steel fillers. Large bolts. Heavy outside angle irons.

Kansas City, Fort Scott & Memphis Railroad.—"Usually build surface crossing angles, supported by 12x12-inch timbers, on ballast. Only use double traffic rail in special cases."

Lake Shore & Michigan Southern Railway Company.—B, all with Easer rails. No framed timbers used, but 7x10-inch ties laid diagonally. Rolled steel fillers. Bolted crossings. Nothing less than 1-inch bolts.

Michigan Central Railway.—A, Broken stone for foundation, and if ground requires it, tile drains. B, all kinds.

Missouri, Kansas & Texas Railway.—A, ordinary ties on ballast. Bisecting angle. B, bolted, rigid crossing.

Nashville, Chattanooga & St. Louis Railway.—A, on heavy cross-ties, placed diagonally so as to give the best support to both tracks. B, no special type of construction. Bolted with cast-steel fillers, riveted to plates. Joints square and mitered according to angle.

New York Central & Hudson River Railroad—A, one foot stone ballast, with necessary provision for drainage, depending upon location. Where necessary drain tile is used. B, for main track crossings. Easer rails, both tracks; for unimportant crossings and street car crossings, no Easer rail except on steam track.

Bolts for 60-lb. and 70-lb. ties.	$\frac{7}{8}$ in	Plates at angles fastened to rail by clips.
" " 75-lb. ties.	1 "	
" " 80-lb. "	$1\frac{1}{8}$ "	
" " 100-lb, "	$1\frac{1}{4}$ "	

Philadelphia & Reading Railway.—Small angles 45 degrees and under. Large angles 45 degrees to 90 degrees. Plate riveted under each throat. Wrought fillers for small angles and Easer rail. For angles from 11 degrees to 26 degrees wings to be bent at angle, *not* jointed. Easer rails for large angles. For 80-pound and heavier 1⅛ inches. Under 80 pounds, 1-inch bolts. Plates ¾-inch thick. In cross-paved streets white oak framed timbers 10x16 inches. If a groove is cut through head of steam rail, it must not exceed 13-16 inch.

Peoria & Pekin Union Railway.—A, "we do not use any special means of draining, as we find cinder ballast sufficient. Our experience with tile drains has been that the action of the crossing churns the mud, causing tile to fill and block drainage." All crossings laid on ties. B, our crossings are of 80-pound rail, reinforcing rails and 1-inch bolts with jam nuts.

The following points are open to discussion:

Should ties or framed timbers be used? If ties, should they be laid bisecting the angles, or at right angles to line having the greatest traffic?

Are crossings laid on framed timbers more liable to creeping action under traffic than if laid on ties?

Are 7x9-inch oak ties suitable under crossings, or should larger ties be used?

For foundation the best ballast obtainable, preferably stone, not less

than 12 inches under the ties, and where good natural drainage is not obtainable, tile should be used.

In general, crossings for heavy traffic should be of large section, not under 75 pounds. They should have wrought-iron or steel fillers, heavy angle bars and Easer rails the entire length, even on very light angles. For 60 to 70 pound steel the bolts should be 1 inch. From 75-pound to 80-pound, 1⅛ inch, and for 90 to 100 pound steel, 1¼ inch.

The best practice seems to be to use plates only at the angles, to support these points properly on the ties and to act as a binder. These plates vary from ⅝ inch to ¾ inch thick.

Where steam tracks cross street railways, or where steam roads of light traffic cross, the Easer rail on the light tracks should be dispensed with, as the crossing would no doubt require replacing for the heavy traffic before it failed for the lighter tracks, and the use of Easer rails on these tracks would be money wasted.

JOINTS AND FASTENINGS.

Bangor & Aroostook Railroad.—Four-hole angle bars, suspended joints. Sternberg bolt. They say of this bolt, which is a grip bolt, with "Ideal" recessed nut, "the most satisfactory we have in use."

Choctaw, Oklahoma & Gulf.—Sixty-five-pound standard, 38-inch 6-hole angle bar, with 21-32 web. Three-fourths-inch bolts, hexagon nuts and nut locks. Seventy-pound standard 38-inch 6-hole angle bar, ⅞-inch bolt with hexagon nuts, nut locks, web 11-16-inch. Supported joints with both sections of rail.

Chicago & North-Western Railway.—Twenty-six-inch 4-hole angle bar with base plates. Seven-eighth-inch bolt, 9-16-inchx5½-inch spike.

Chicago, Rock Island & Pacific Railway.—Twenty-four-inch "Continuous" joint 4-hole, ⅞-inch Harvey grip bolt. Ideal nut, no nut locks. Report very favorably on the "Harvey Grip" bolt.

Denver & Rio Grande Railroad.—Eighty-five-pound steel, 4-hole suspended joint. Weight 52 pounds per pair; 65-pound steel, 6-hole supported joint, weight 68 pounds per pair.

Great Northern Railway.—Thirty-six-inch, 6-hole angle bar, weight 13-16 inch, ¾-inch bolts.

Elgin, Joliet & Eastern.—Thirty-eight-inch, 6-hole angle bar, spike holes through flange instead of notches.

Illinois Central Railroad.—Forty-inch, 6-hole angle bars, ⅞-inch bolts, Verona nut locks.

Intercolonial Railway of Canada.—Forty-two-inch fish plates, with 6¾-inch bolts, 26-inch fish plates with 4⅞-inch bolts.

Kansas City, Fort Scott & Memphis Railway.—Twenty-four-inch angle bar, ¾-inch rolled steel Harvey Grip bolts, no nut locks. "We have used the Harvey Grip Bolts for a long time, probably 10 years. We think we get better results than with V threads and nut locks.

Lake Shore & Michigan Southern Railway.—Twenty-four-inch angle bars, ¾-inch bolts, Harvey Grip.

Michigan Central Railroad.—Ordinary angle bar, long truss joint, Little "Fisher Bridge Joint." Report favorably on the latter two.

Missouri, Kansas & Texas Railway.—Continuous joint.

Nashville, Chattanooga & St. Louis Railway.—Eighty-pound angle bars, 6⅞-inch bolts, spring nut locks, all nuts on *outside*.

New York Central & Hudson River Railroad.—Eighty-pound, 36-inch, 6-hole bar, ¾-inch Grip bolts. Weight of angle bars per pair, 64½

pounds. No nut locks. Tie plates. One hundred-pound, 36-inch, 6-hole angle bar, ¾-inch Grip bolts. Weight pair, 80-pounds, 3-tie joints not less than 5 inches between ties.

Peoria & Pekin Union Railway.—Twenty-eight-inch 6-hole angle bar, drilling 2 inches-5 inches-5 inches, ⅞-inch bolts. Verona "Tail" nut locks.

Philadelphia & Reading Railroad.—Ninety-pound, 28-inch, 6-hole angle bar. Bolted alternate inside and outside joint, ⅞-inch bolt and nut lock. Web ¾-inch, 90-pound 30-inch 6-hole joint angle bar, ⅞-inch bolt and nut lock, web 11-16 inch.

Rock Island & Peoria Railway.—Eighty-pound rail, "Continuous" joint, 4⅞ inch Harvey Grip bolts. Ideal recessed nut. No nut locks. Twenty-four-inch suspended joint, nuts on inside prior to 1901. Alternate inside and out, and spikes through flange of angle bar from 1901.

St. Louis & San Francisco Railroad.—Twenty-four-inch heavy angle bar, ⅞-inch Harvey Grip bolt. "We use Harvey Grip bolt, and it gives satisfaction."

Union Pacific Railroad.—Seventy-pound, 29-inch, 6-hole, ¾-inch bolts, hexagon nuts and nut locks; 80-pound, 29-inch, 6-hole, ⅞-inch bolts, hexagon nuts and nut locks; 90-pound, 29-inch, 6-hole, ⅞-inch bolts, hexagon nuts and nut locks. All 2-tie suspended joint. "We tried the Harvey Grip bolt, but found they gave us no better service than the plain bolt with the nut lock, and cost more money.

Union Pacific Railway.—Seventy-pound steel, 29-inch, 6-hole angle bar, hexagon nuts, ¾-inch bolts, nut locks, 11-16-inch web, 2-tie joint and tie-plates 10 inches between joint ties. Weight 48 pounds per pair; 80-pound, same, except ⅞-inch bolt, ¾-inch web. Weight pair, 55¾ pounds; 100-pound, same, except 13-16-inch web. Weight 65 pounds per pair.

Vandalia Line.—Seventy-pound, angle bars, 6-hole joints, ⅞-inch hexagon nuts, with Verona and National nut locks; spikes, 9-16x5½.

The joint in most general use is the 4 or 6-hole angle bar, running from 24 inches to 40 inches in length and suspended on two or supported on three ties.

The shortest 6-hole angle bar seems to be 28 inches for a suspended joint.

Probably an angle bar should have as heavy a web section as the rail section will permit.

Where the supported joint is used the angle bar should be long enough to allow room for tamping the joint ties, and this should not be less than 5 or 6 inches.

Many roads are using special types of joints, but where they differ from the ordinary angle bar they are a "truss" or "bridge" type of joint, and as such joints cannot be used in connections around switches, crossings or interlocking plants, it might be advisable for some roads not to adopt them, especially as it is doubtful if they are superior, all things considered, to angle bars.

It would seem advisable for any company to use as few different makes of joints or angle bars as possible, otherwise there will be continual trouble from the multiplication of styles of joints and fastenings.

Bolts with the common V thread and nut lock are largely used, but it is a question if this is now the best practice, since so many roads report excellent results from grip bolts, using the recessed nut and no nut locks.

There are several types of grip bolts, but the principle is the same, i. e., a slightly different pitch of thread on bolt and nut, causing the latter to jam tightly on the bolt. The recessed nut seems to prevent battering of the thread, and is indorsed quite generally. In general, these grip bolts are made with rolled thread.

The objection to the grip bolt seems to be the cost, and also the fact that it is a patented affair.

MAINTENANCE OF GAUGE.

By C. L. Addison.

Proper Method of Spiking.—In considering the subject of gauge, it seems pertinent to call attention to the necessity of having properly constructed tools.

The track gauge is the most important tool furnished the trackmen and its accuracy is of such importance that it is considered desirable to test all gauges before issued. It is of equal importance that the length of the tool remains constant.

To insure this quality, the crossbar should be of material not subject to change of length through rough or careless handling.

Gauges constructed entirely of metal do not meet this requirement, since bending of crossbar materially shortens the length of the tool. Attention is called to the fact that bent gauges one-eighth inch short have been frequently observed in use.

While lightness and neatness of design of this class of tool are conceded, the heavier and stiffer form of gauge constructed of suitable wooden crossbar with metal endpieces more nearly satisfies the requirements.

In use the gauge should be placed squarely across the track and the rail to be gauged held firmly against the head of the gauge.

Outside spikes should be started first and both outside and inside spikes driven at the same time, with faces of spikes in contact with and parallel to the base of the rail.

The gauge should remain upon the rails until the spikes are fully driven.

The final blow in driving should be just sufficient to bring the head of the spike in contact with the base of the rail without straining the head of the spike.

To prevent the tie from assuming a position at an angle with the rails, the system commonly known as "cross-spiking" should be employed. The outside spikes of both rails should be on the same side of the center line of the tie and the two inside spikes on the opposite side.

Spikes should be started at right angles with the tie, and this position should be maintained during driving. The practice of straightening up spikes which have been partly driven at an angle should be discouraged. This "straightening up" not only bends the spike, but compresses the fibre of the timber, causing an enlargement of the spike hole. This is particularly noticeable where comparatively soft wood ties are in use, and practically destroys the power to resist lateral or vertical pressure.

Methods Used to Prevent Spreading of Track and Canting of Rails.—On account of the shortness of time, replies from only 25 roads have been received in answer to the above subject.

Of the roads replying to the questions, it would appear that 44 per cent of these roads use tie-plates, 32 per cent use tie-plates and rail braces, and 12 per cent use rail braces only, to prevent the canting of rail and consequent widening of gauge.

Of the remaining 12 per cent, one road uses inside guardrails to hold off the wheels and reduce the lateral pressure at point of flange contact. Another road adzes the surface of the ties under the rail, so as to cant the rail toward the center of the track. Other roads double spike the outside of the rail, and one road replies that the canting of rails has never been observed.

The forces which tend to widen the gauge of tracks at curves are of two kinds:

First, lateral thrust, considered simply as lateral thrust; due to the pressure exerted by the wheel flange upon the rail at the point of contact; caused by centrifugal force, augmented by the sway of imperfect equipment. So considered, and assuming no change in the surface of the tie under the rail, this force is readily resisted by the outside spikes, on curves of large radius, and by the spikes, reinforced by rail braces on curves of smaller radius. This presupposes the use of ties of hard or moderately hard woods.

The second, and, by far, the more destructive force, is the resultant of the vertical load on the head of the rail and the above-mentioned horizontal or lateral force acting at the point of flange contact.

The resultant force acts in the direction of a line, extending, approximately, from the inside edge of head to a point somewhere between the center of the rail and the outside edge of the base; depending upon the speed of the train and the amount of elevation of the rail.

As a result of this force, the fibre of the tie immediately under the rail is compressed to the greatest extent at the outside edge of the base of the rail.

In combination with the sawing action of the rail on the tie, due to the undulatory movement of the rail, the destruction of fibre takes place with greater or less rapidity, depending upon the degree of hardness of the tie. As the destruction of fibre is greatest at the point of greatest pressure, it is obvious that as the rail cuts into the tie, the rail will assume a canted position and the original gauge of the track will be widened. As before stated, the rail brace satisfactorily resists lateral thrust only, but absolutely fails to resist the canting of the rail. The same forces which tend to cut away the tie under the outer edge of the rail depress the portion of the brace in contact with the rail, raising the outer end and drawing the spikes. As a matter of fact, immediately the cutting of the tie commences the rail brace becomes a lever of the first class, with its fulcrum on the tie, near the outer edge of the rail. The weight is the wheel load and the power, the holding power of the spikes. The power arm, as far as two

of the spikes are concerned, being practically the same as the weight arm of the lever. It is obvious that rail braces in this capacity must fail absolutely. The properly designed tie-plate is the only known device which will prevent the cutting of the ties and the consequent canting of the rail, and, in addition, prevents the outward movement of the rail due to lateral thrust by bringing into use the inside spike to resist this action. To secure the best results tie-plates should be used on *every* tie in the curve. We do not consider the practice of tie-plating every second or third tie desirable, inasmuch as the unplated ties, in offering less resistance than the plated ones, subject the rail to an unusual torsional strain between the plated ties. It is respectfully recommended that curves of 3 degrees and upwards be tie-plated, using tie-plates on every tie, and that all softwood ties in curves of any degree be plated. By so doing the resistance offered by the plated soft tie approximates the resistance of the unplated hardwood tie.

Widening of Gauge on Curves.—With regard to the widening of gauge of track at curves, no uniform practice can be said to exist on American railroads.

In response to circular No. 16, replies have been received from 25 roads, representing 47,600 of miles line. Condensed summary of the practice of these 25 roads as follows:

PRACTICE OF 25 AMERICAN ROADS IN WIDENING GAUGE OF TRACK ON CURVES.

Roads.	Increase commence with	Range of increase	Maximum increase.
1	12°		$\frac{3}{4}''$
1	8°	For 1° inc. $\frac{1}{32}$	$1''$
2	6°	" 1° " $\frac{1}{16}$ to $\frac{1}{8}$	$\frac{1}{2}''$ and $\frac{3}{4}''$
1	5°	" 1° " $\frac{1}{16}$	$\frac{1}{2}''$
1	4°–30′	" 1° " $\frac{1}{32}$	$\frac{1}{2}''$
6	4°	" 1° " $\frac{1}{32}$ to $\frac{1}{2}$	$\frac{1}{4}''$ to $1\frac{1}{4}''$
5	3°	" 1° " $\frac{1}{32}$ to $\frac{1}{2}$	$\frac{1}{2}''$ to $1''$
1	2°	" 1° " $\frac{1}{16}$	$\frac{1}{2}''$
1	1°	" 1° " $\frac{1}{24}$	$\frac{1}{4}''$
6	No increase.		

At a meeting of the American Railway Association, held in New York, October 6, 1897, the report of the Committee on Standard Track and Wheel Gauges contained replies from roads aggregating 94,276 miles of line.

The condensed summary of practice of 104 roads, in widening gauge of track on curves, from "Engineering News," as follows:

TABLE NO. 2.

Roads.	Increase commencing with	Range of increase.	Maximum increase.
18	1°	1° inc. $\frac{1}{32}''$ to $\frac{1}{4}''$	$\frac{1}{4}''$ on 5 roads
5	2°	2° " $\frac{1}{16}''$ to $\frac{1}{4}''$	$\frac{3}{8}''$ on 2 "
15	3°	3° " $\frac{1}{16}''$ to $\frac{3}{8}''$	$\frac{2}{5}''$ on 1 "
10	4°	4° " $\frac{1}{16}''$ to $\frac{1}{2}''$	$\frac{1}{2}''$ on 30 "
16	5°	5° " $\frac{1}{16}''$ to $\frac{1}{2}''$	$\frac{5}{8}''$ on 5 "
7	6°	6° " $\frac{1}{8}''$ to $\frac{1}{2}''$	$\frac{3}{4}''$ on 24 "
3	8°	7° " $\frac{3}{16}''$ to $\frac{21}{32}''$	$\frac{9}{16}''$ on 2 "
1	9°	8° to 9° " $\frac{1}{8}''$ to $\frac{3}{4}''$	$\frac{15}{16}''$ on 2 "
2	10°	10° to 12° " $\frac{1}{8}''$ to 1″	1″ on 8 "
1	13°	13° " $\frac{1}{8}''$ to 1″	$\frac{13}{16}''$ on 1 "
1	21°	14° to 20° " $\frac{1}{4}''$ to 1″	
25	No increase of gauge on curves.		

Of the 94,276 miles of line reporting on this subject:

16,239	miles	report	no increase of gauge on main track.			
307	"	"	increase	from	12°	upwards.
4,117	"	"	"	"	8°	"
2,967	"	"	"	"	6°	"
3,331	"	"	"	"	5°	"
25,387	"	"	"	"	4°	"
19,111	"	"	"	"	3°	"
7,307	"	"	"	"	2°	"
15,510	"	"	"	"	1°	"
94,276						

The variation in practice, as shown by Tables 1 and 2, is undeniably great. While it is impossible to establish a rule for gauge-widening which will apply in all cases, good practice does not seem to warrant such great variation as shown.

Since it is the locomotive, differing in length of wheel-base and truck arrangement, which determines the amount of widening of gauge, as well as the rate of widening, it may be proper to quote from the reports of the American Railway Master Mechanics' Association for 1899 and 1900, in order to establish the figures used in subsequent calculations.

The practice of flanging all drivers of the ten-wheel Mogul and Consolidation type of engines is gaining favor with the heads of mechanical departments and has been reported upon favorably by the committee on the subject. The extent to which this practice has been carried, from report of 1899, as follows:

Number of engines owned by roads replying, 12,265.

Mogul type....	1,183
10 Wheel type.........	2 284
Consolidation type.....	2,066
	5,533

All drivers flanged.		1st and 3d flanged.	2d and 3d flanged.	1st and 4th flanged.	1st, 3d and 4th flanged.	Total.
Mogul.........	440	743	......	......	......	1,183
10 Wheel.....	534	1,048	702	......	......	2,284
Consolidation	348	......	......	1,313	405	2,066
	1,322	1,791	702	1,313	405	5,533

	Longest rigid wheel base.		Longest total wheel base.	
	All flanged.	Partly flanged.	All flanged.	Partly flanged.
Mogul	16′ - 1½″	16′ - 0″	23′ - 0″	23′ - 10½″
10 Wheel	14′ - 4″	16′ - 0″	24′ - 10″	26′ - 6″
Consolidation...	16′ - 3″	16′ - 3″	24′ - 2″	24′ - 6″

"*Swing motion* trucks are used with the three types of engines having all tires flanged, the motion being 1½ inches each side of the center.

"Same practice prevails with Mogul, Consolidation and many ten-wheel engines haveng tires *partly* flanged, but about *50 per cent* of the ten-wheel engines with tires *partly* flanged have *rigid* trucks.

"In all types the practice when the above classes of engines leave shops is to have lateral motion of ⅛ inch in each driving box and same lateral in each engine truck box. With tires partly flanged, the distance between backs of flanges for each type of engine before mentioned appears to be 4 feet 5¼ inches.

"In cases of engines having flanged tires on all driving wheels the same practice prevails for Mogul and ten-wheel engines. Practice with Consolidation engines having flanged tires on all driving wheels is to have the distance between flanges of 1st and 4th pairs of wheels 4 feet 5⅛ inches and between the backs of flanges of 2d and 3d pairs of wheels 4 feet 5¼ inches."

As will be seen from the first part of the report, 50 per cent of all ten-wheel engines with partly-flanged drivers now in service on American roads are equipped with rigid trucks. This class of engine, as well as the standard eight-wheel type, which, in many cases, is equipped with rigid truck, constitute the limiting engines in the consideration of gauge widening. Consolidation, Mogul and ten-wheel types with drivers all flanged are invariably equipped with swing trucks and would constitute limiting types if the swing motion is not sufficient. As the Master Mechanics' Association recommend 1½ inches swing motion, it is presumed that this distance it not to be erected and unless 1½ is enough to allow the truck sufficient motion to permit the leading driver flange to touch the outside rail, a condition the Master Mechanics wish to avoid, these engines will become a limiting class and the values of quantities entering into the formulas suggested by Mr. William H. Searles in Engineering News of Dec. 2, 1897, will have to be modified from those shown on accompanying diagrams to meet the requirements imposed by all-flanged drivers.

In quoting from the reports of the Master Mechanics' Association it is not intended to convey the impression that the roadway departments are in sympathy with the movement to save flange wear at the expense of the track.

Engines of the types mentioned above are in service to the extent of 20 per cent, and the use cannot be considered general.

In dealing with the subject of gauge widening, these engines have not been considered as constituting a limiting class, and, inasmuch as the proper values have not been introduced into the formulas to meet the requirements imposed by all-flange drivers, the report is necessarily incomplete.

The formulas referred to above, as suggested by Mr. Searles, are formulas for the degree of a curve, having given either the middle ordinate and chord or a side ordinate at a given distance from the middle of the chord and its chord, based on the well-known approximate formula $m = \frac{C^2}{8R}$

In applying these formulas to the formation of the accompanying diagrams, Nos. 1, 2 and 3, it has been considered desirable to calculate the radius rather than the degree of the curve, thereby avoiding a second approximation. The formulas used, as follows:

$$\text{For rigid truck } R = \frac{6ab}{p} \qquad (1)$$

$$\text{For swing motion truck } R = \frac{6ab}{p + \left\{\frac{sb}{a+b}\right\}} \qquad (2)$$

in which a represents the distance from the center-pin of a four-wheel truck or the center of the axle of a two-wheel truck to the center of the front-flanged driver axle expressed in feet.

b represents the distance from the center of the front-flanged driver axle to the center of the rear-flanged driver axle, expressed in feet.

p, the flange play, including the widening of gauge, if any, in inches. Assumed as ⅝ inch for flange play.

s, the side motion in inches, assumed as one inch.

In constructing the accompanying diagrams it has been assumed that ⅝-inch flange play and 1-inch side motion are minimums, and it is thought that by the use of the above minimum values the radii shown on the diagrams will allow sufficient play for an engine to move freely through the curve.

These diagrams have been constructed for track at gauge and also for gauge widened at rate of ⅛ inch up to 1 inch maximum widening.

For engines equipped with rigid truck formula (1) $R = \frac{6ab}{p}$ is used as before stated. An examination of the plans of 40 eight and ten-wheel engines constructed for 20 different roads during the last four years shows that the product of a and b in these engines varies from 70 to 124. (See diagram 2, right side.)

To illustrate, assume an eight-wheel passenger engine, distance from center of truck to first driver, 12 feet; distance between drivers, 7 feet. Product of a and b in this case is 84. Diagrams show that this engine with track at gauge should pass around curve of 797 feet radius, or, ap-

proximately, 7 degrees 10 min., and with track 1 inch wide gauge, should pass around curve of 307 feet radius.

Diagram 1 and diagram 2 (left hand) have been constructed for eight and ten-wheel engines with swing trucks, using formula (2) $R = \dfrac{6\,a\,b}{p + \left\{ \dfrac{b\,s}{a+b} \right\}}$

As the value of the denominator is dependent upon b in this case, diagrams have been constructed for certain values of b and for certain relations between a and b. If the engine with rigid truck before described, be equipped with spring truck, the distance a and b being respectively, 12 and 7 feet, as before, the curve around which this engine will pass will be found from diagram B, sheet 1, where b equals 7 feet. With a = feet and b = 7 feet, a = 1.7 b. Referring to diagram, it will be seen that this engine with swing truck will pass around curve of 500 feet radius with track laid at gauge, and around curve of 250 feet radius with curve 1-inch wide gauge. An examination of the plans of the 40 engines before mentioned show that the distance (a) from the center of truck to the first flanged driver axle varies from 1.3 to 2.2 times the distance (b) between flanged drivers.

An examination of the plans of Consolidation engines shows that the distance between extreme drivers varies from 14 to 17 feet, and that the distance (a) between the center of truck-wheel axle and first flanged driver axle varies from .4 to .6 of the distance (b) between the first and last flanged driver axles. Diagrams 3A, 3B, 3C and 3D constructed for Consolidation engines.

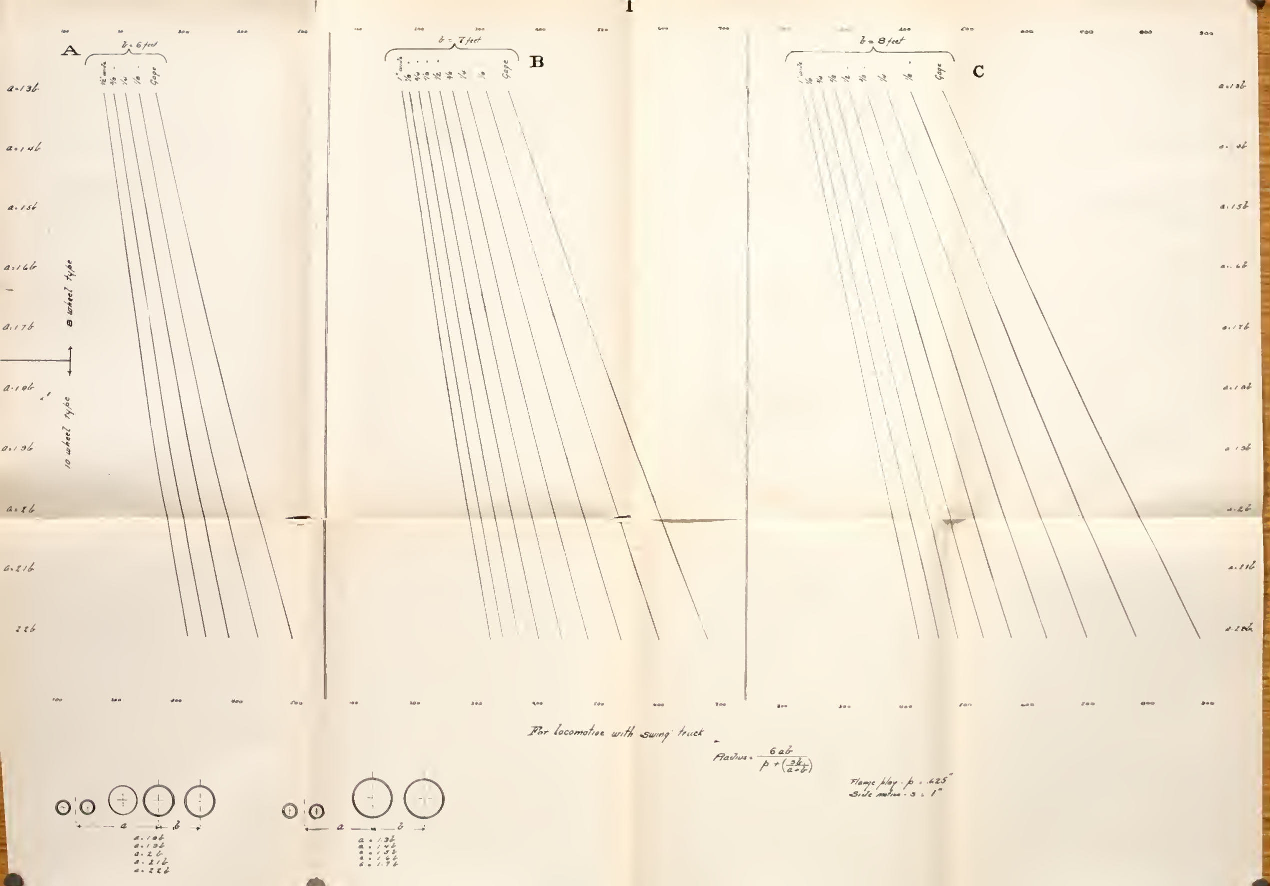
Assume Consolidation engine distance (a) between center of truck axle and the center of first flanged driver axle 8.5 feet, and distance (b) between center of first and last flanged driver axles 15 feet. In this engine the distance between center of truck axle and first flange driver axle is approximately .56 times the distance between extreme flange driver axles. Referring to diagram 3B for b = 15 feet, it will be seen that for a = .56 b this engine will pass around a curve of 596 feet radius when track is laid at gauge and around a curve of 333 feet radius when track is laid 1 inch wide gauge.

In conclusion, the attention of the Committee is called to the fact that any table for the widening of gauge on curves will not be applicable to all classes of engines. A glance at the accompanying diagrams will clearly show this to be a fact. Inasmuch as every railroad is running over its lines some engine which can be considered as a limiting engine, it must follow that each road will be obliged to establish a system of gauge widening peculiar to itself.

GUARD RAILS.

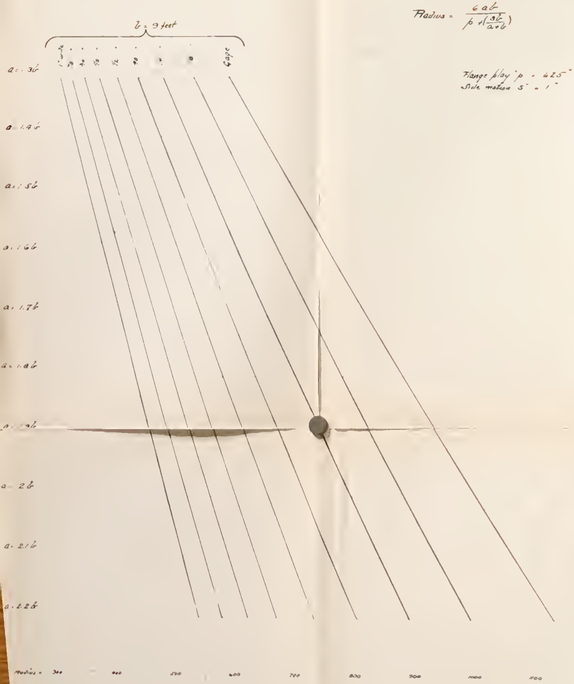
By Wm. W. Gwathmey, Jr.

A guard rail is a device placed between the track rails for two purposes—first, to prevent derailments of car wheels at frogs and switches and on curves of short radius; second, to control car wheels and prevent their leaving the ties, causing the wreck of cars or bridges.

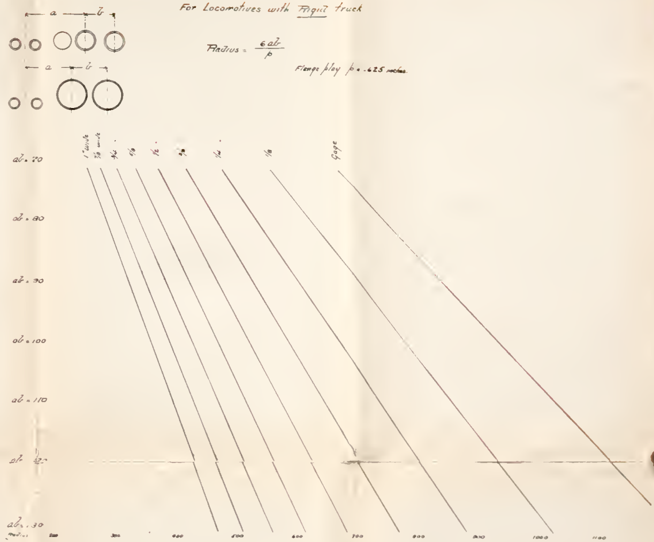


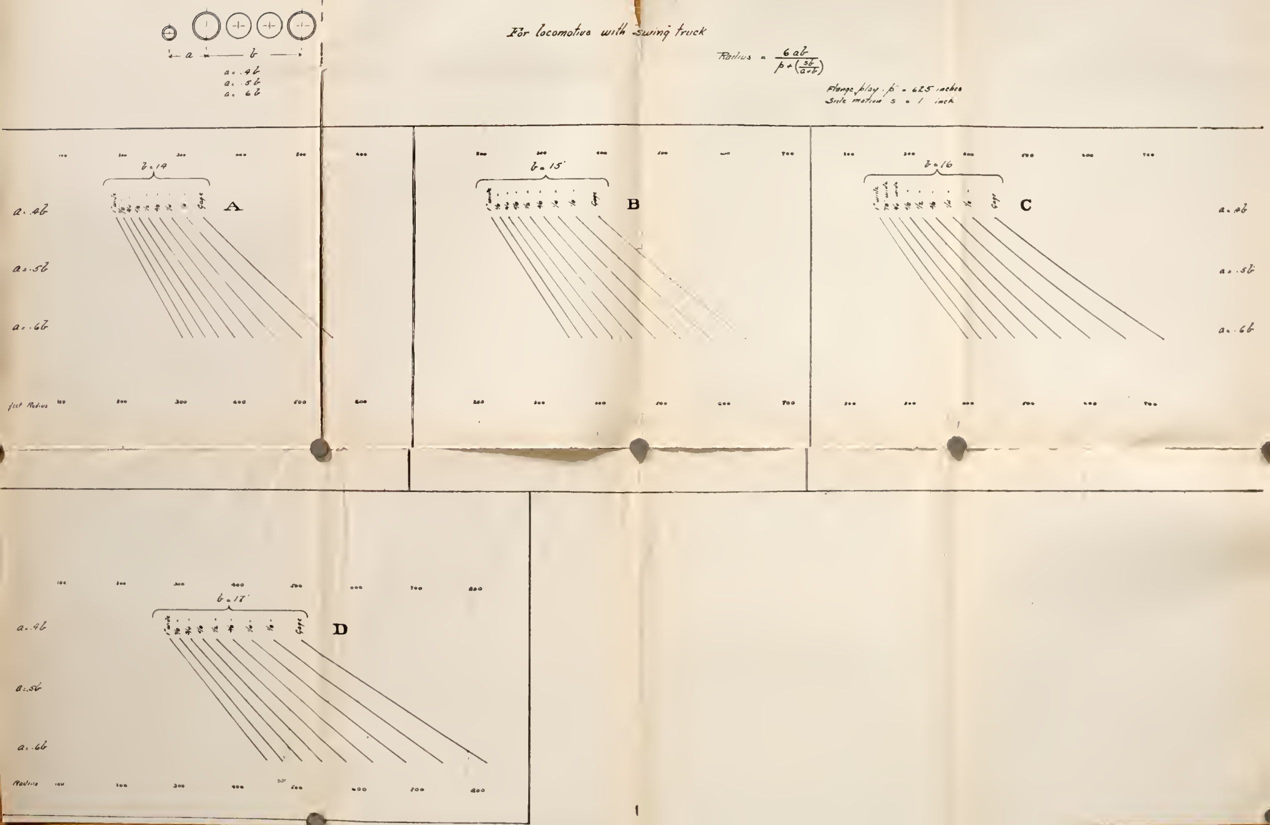
A
b = 6 feet
B
b = 7 feet
C
b = 8 feet
Gage
a = 1.3b
a = 1.4b
a = 1.5b
a = 1.6b
a = 1.7b
a = 1.8b
a = 1.9b
a = 2b
a = 2.1b
2.2b
8 wheel type
10 wheel type
For locomotive with swing truck
Radius = 6ab / p + (sb / a+b)
Flange play - p = .625"
Side motion - s = 1"

For locomotives with Swing truck



For Locomotives with Rigid truck




For locomotive with swing truck
Radius = 6 ab / p + (sb / a+b)
Flange play p = .625 inches
Side motion s = 1 inch
a = .4b
a = .5b
a = .6b
b = 14
A
b = 15
B
b = 16
C
b = 17
D
Gage
feet Radius
Radius

Guard rails are chiefly used to prevent derailments at turnouts, and are placed, generally, with center of guard rail opposite the frog point. Some engineers prefer to place the guard rail with the center from one to three feet nearer the switch, and to this there is no objection. The guard rail should be not less than ten feet long for yard turnouts, and not less than fifteen feet long for main line turnouts. The guard rail should be the same height as the main track rail. The clearance between gauge lines of guard rail and main rail should be not less than one and three-quarters (1¾″) inches nor more than two (2″) inches. Accurately speaking, the gauge lines of the guard rail opposite the point of frog should be placed not less than four feet six and three-quarter inches (4′ 6¾″) from the gauge line of the frog point.

The flanges of guard rails should be planed off to admit the gauge line of guard rail being placed with proper clearance from main rail, and to allow space for spiking the main rail. Not less than five feet of the middle section of the guard rail and the ends of the straight section should be bent in such manner that the gauge line of the guard rail shall open gradually from the main rail until the clearance between the gauge lines of the guard and main rails shall be not less than four inches, and, preferably, six inches.

Guard rails should be securely fastened to the main rail with not less than two malleable iron clamps fitted with keys and have adjustable wedged-shaped blocks between main rail and guard rail for maintaining the correct guard rail clearance, or bolted through cast-iron filling blocks. They should be securely spiked to the cross-ties, and braced with not less than four rail braces.

We do not recommend placing guard rails in advance of facing split switches except where the turnout leaves the track on a curve, at which point the wheel flanges bear strongly against the outer rail. Guard rails should be used in connection with special grade crossings and slip-switch devices used at yards and terminals to square trucks leaving a sharp turnout and approaching rigid frog points.

We do not recommend guard rails on curves of more than three hundred feet radius. On curves of two hundred feet radius and less guard rails are necessary.

The Committee does not recommend the use of filling blocks for foot-guard protection unless their application is extended to the ends of guard rails, at switches, crossings frogs, or other points in track where trainmen are subject to similar danger as at the heels of frogs.

We recommend the use of guard rails on through bridges and high-deck bridges, trestles and viaducts. The guard rails should be placed inside the track rails, the gauge lines of the guards being placed seven inches from the gauge lines of the track rails. At the ends approaching the structure the ends of the guard rails should be drawn gradually to a point at the center of the track and securely bolted. The rails at this point should be planed down, so as not to catch hanging brake rods or beams under trains. The guard rails should be securely spiked to the ties after the manner of the main rails. The curved approaches should

be braced on the inside. After considering bridge guards made of iron angles and wooden guards with angle-iron protection, we recommend the use of ordinary railroad rails the same height as the track rails.

Your Committee would be glad to have the experience of members of the Association concerning rerailing devices used in connection with bridge guards.

The above recommendations are respectfully submitted to the Committee for discussion and amendment.

The practice on the roads named below is as follows:

Atlantic, Valdosta & Western Railway.—Guard rail 15 feet long, bent to a crescent shape with 1¾-inch flangeway at point of frog, and 4-inch opening at each end for 4-foot 8½-inch gauge. For 4-foot 9-inch gauge give 2-inch flangeway at frog. Foot-guards are necessary and can be made of wood and placed at heel of frog and switch.

Bangor & Aroostook Railroad.—Flangeway 1¾ inches, except where curvature and widened gauge calls for more. The Hart foot-guard is used.

Buffalo & Susquehanna Railroad.—Spacing for flangeway for guard rails are 1¾ inches, the gauge of track for frogs and switches always being 4 feet 8½ inches. The curves of straight line guard rails are ordinarily kept in place and from overturning by three rail braces, with a few exceptions in yards, where the guards are bolted to the main rail with three ¾-inch bolts, with heavy washers, made of old fish-plates, on the outside, no spacing blocks being used between the main rail and guard rail. No foot-guard protections are used.

Bismarck, Washburn & Great Falls Railway.—Guard rails are 15 feet long, with 2-inch flangeway. Wooden foot-guards are used.

Chicago & Alton Railway.—Guard rails 15 feet long; flangeway 1⅞ inches, plus for gauge widened for curvature. Guards are placed opposite midway between frog point and joint of spring rail. Guards are held in place by spikes and braces, and are bolted through cast-iron filler blocks to the main track rail. Guard rails for rigid frogs are placed centrally, opposite the frog points, and spiked and braced in position. Clearance on bridge guards is 8 inches.

Chicago & Eastern Illinois Railroad.—Length of guard rail 15 feet, clearance 1¾ inches. Spiked to tie and bolted to main rail through filler blocks. Clearance for bridge guard rails is 8 inches.

Cincinnati, Hamilton & Dayton Railroad.—Extract from Book of Rules: "Guard rails must be placed not to exceed 2 inches from the main rail, and in accordance with the standard plans and diagrams.

Chicago, Milwaukee & St. Paul Railway.—Flangeway 1⅞ inches. Hart foot-guard.

Choctaw, Oklahoma & Gulf Railroad.—Flangeway spacing throughout is 2 inches, with guard rails flared at the ends. No foot-guards.

Chattanooga, Rome & Southern Railway.—Flangeway 2⅛ inches.

Delaware, Lackawanna & Western Railroad.—Length of guard rails 15 feet at spring frogs and 7 feet 6 inches at rigid frogs. Guard rails at spring frogs are fastened with 3 cast filler blocks and 4 bolts with braces; at rigid frogs they are fastened with two bolts through cast filler blocks and braces.

Denver & Rio Grande Railroad.—Flangeway 1¾ inches for main line and 2 inches for yards. No foot-guards used.

Duluth, South Shore & Atlantic Railroad.—15 (15) feet long, bent 12 inches each side of frog point with 2-inch flangeway. "In my experience this is the only guard rail."

Elgin, Joliet & Eastern Railway.—Flangeway 1¾ inches. Cast-iron guard filler and foot-guard.

Georgia Railroad.—Spacing of flangeway 2¼ inches. No foot-guards.

Houston & Texas Central Railway.—Flangeway 2 inches. No foot-guards.

Illinois Central Railroad.—Length of guard rail 15 feet. Flangeway 1⅞ inches, guard rail placed so that when one end of a 4-foot 8½-inch gauge is placed against the frog point, the face of the guard rail will be 1⅞ inches from the other end of the gauge. The guard rail is placed centrally, opposite point of frog. The guard rail is spiked to the ties, and bolted to the main rail through cast iron filler blocks. The guard rail has 6-inch flare at each end.

Foot-guard protection is applied at each end of the guard rail and at each end of frog.

Intercolonial Railway of Canada.—Spacing of flangeway is 1¾ inches. Foot-guards have iron blocks filled with either wood or waste.

Kansas City, Fort Scott & Memphis Railway.—Standard flangeway is 1⅞ inches. Hart foot-guards used in yards.

Louisville & Nashville Railroad.—Extract from Book of Rules: "The gauge side of the frog guard rails must always be placed 4 feet 6¾ inches from the point of frog, regardless of the gauge of track."

"Frogs and guard rails must be blocked or provided with foot-guards in those states where it is required by law."

Central Railroad.—Length of guard rails 15 feet, placed with center opposite point of frog, spiked and braced. The spacing of flange rail from main line rail with vertical sides to their heads is 2 inches opposite the frog, and for same distance each way beyond this 2-inch space is maintained (see blue print). In connection with slip switches with rigid center frogs, we put in position a guard rail about 1½ inch from the rail for squaring trucks which have come through a "Y."

In general use, wooden frog and switch blocking is used for foot-guard protection, but in the state of Ohio we are using metal foot-guard protection, as required by law. Jordan Bridge Guard is used.

Missouri, Kansas & Texas Railway.—Flanges of rail at guard rails are placed close together with ends open 6 inches. Wooden foot-guard is used, cut to fit different patterns of rail, which is driven in between webs of rails.

Missouri Pacific Railway.—Spacing of flangeway is 1⅞ inches. Foot-guard protection at frogs always.

Nashville, Chattanooga & St. Louis Railway.—Length of guard rail 15 feet. For 4-foot 9-inch gauge a flangeway of 2 inches is required. Our gauge is gradually being changed to 4 feet 8½ inches, and flangeway for this gauge is 1¾ inches. Guard rails are spiked and braced and placed with 10 feet of guard rail toward switch point, from point opposite frog point. Foot-guards are made of wood. No other safety devices. No guard rails on bridges other than timber guards.

New York Central & Hudson River Railroad.—Guard rail 15 feet long, with flangeway 1¾ inches, opened to 5 inches at ends. Flangeway is increased when gauge of track exceeds standard. Guard rail is spiked and braced, and placed with center 2 feet 3 inches ahead of frog point. All guard rails, frogs and switches are blocked with wooden fillers.

New York, New Haven & Hartford Railroad.—Length for spring frogs 15 feet, for rigid frogs 10 feet. Clearance 1¾ inches. Guard rails are fastened with two clamps and filling blocks. Three feet at each end of rail curved. Guard rails on bridges have 8-inch clearance, and rails are drawn to a point 60 feet from end of bridge.

Pennsylvania Railroad.—Length of guard rails 15 feet, clearance of

flangeway 1¾ inches, placed opposite frog point, with center 1 foot ahead of frog point. Guard rail is straight for 3 feet in middle, and the 6 feet on each end is curved to give 4-inch clearance at ends. Guards are spiked and braced, and clamped to main rail with 2 heavy malleable iron clamps and wedges. Guard rails on bridges have clearance of 7 inches, and ends are brought to a point 60 feet from end of bridge.

Peoria & Eastern Railway.—Spacing of flangeway is 1¾ inches. A cawt block is used and bolted to both rails by one ⅞-inch by 7-inch bolt, thus insuring the correct clearance at all times. Foot-guard protection is provided by the use of wooden pieces or gravel.

Rock Island & Peoria Railroad.—Length of guard rails for main line is 15 feet. Flangeway is 1⅞ inches, and is maintained by case blocks and ⅞-inch bolts. Deflection of wing is 1 inch in 10 inches. Foot-guard protection is provided by wood for 60 pounds and lighter steel, with cast blocks for 80-pound steel.

Seaboard Air Line Railway.—Length of guard rails 15 feet. Flangeway 1¾ inches. Guard rails are spiked and braced, but not fastened to main rail. Center of guard rail is placed opposite point of frog. Standard bridge guard is to be adopted. We have never seen the necessity, in our experience, for foot-guard protection.

St. Louis & San Francisco Railway.—Spacing of flangeway is 2 inches. Wooden foot-guards are provided.

Union Pacific Railroad.—For guard rails, see blue print of standard. Hart foot-guard protection is used.

Vandalia Line.—Spacing of flangeway is 2 inches with 4-foot 9-inch gauge, and 1¾ inches with 4-foot 8½-inch gauge. Foot-guard protection not generally used. Those in use are wooden blocks, about 18 inches long, fitted under heads of rails and spiked to cross-ties.

Wisconsin Central.—Flangeway should be 1⅞ inches. Cast-iron blocks used at end of guard rail with bolts passing through the guard rail, main rail and block, are used for foot-guard protection.

Philadelphia & Reading Railway.—Guard rails at frogs are 15 feet long, with flangeway of 1⅞ inches. Guard rails are spiked and braced, and placed with center 2 feet 8 inches ahead of frog point. Guard rails are used at facing point split switches, are 9 feet long, with a flangeway of 1⅞ inches. Twelve inches of the rail nearest switch is curved for an opening of 4 inches at extreme end of rail, and at the other end 5 feet of the rail is curved for an opening of 5 inches at end. The end of guard rail is placed 3 inches from switch point, and the rail is spiked and braced. The guard rails are placed on the side of the open switch point. At the end of double track the guard rail is placed on the side of the closed point. At facing point junctions, a guard rail is placed on each side, with a 2-inch flangeway for a 4-foot 8½-inch gauge, and for a wider gauge there must be a corresponding increase of throat.

TOOLS.

By W. B. Poland.

I present herewith Sub-Committee report No. 5 on tools.

(a) Track Lining Tools, Various Kinds.—I submit recommendations in regard to certain tools without attempting to establish standards.

(1) Bars, Claw.—The goose-neck bar is not recommended on account of variation in the curve, which often results in bending spikes in drawing. The straight claw bar with long heel should be used.

(2) Bars, Lining.—Should be of steel, just as light as they can be made, and not bend under track throwing. They should have wood chisel

point, 1½ inch square at lower end for 15 inches, and taper to ¾ inch at the top, length 5 feet 6 inches.

(3) Bars, Tamping—Lower edge should be 4 inches by ½ inch, upper end chisel-pointed.

4. Bender, Rail.—For curving rail and heavy rail bending the roller type of bender should be used. For bending stock rails, etc., a "jim crow" will do.

(5) Boards, Elevation (or Sighting) for Surfacing Track.—Should be 12 to 14 feet long, painted black, with ¾-inch white strip, the top of which is used for sight line. This strip is in two equal parts, which can be raised or lowered on the board independently by pegs and series of holes ¼ inch apart. The board is set level by means of adjustable iron legs. In surfacing around a curve the outer strip is raised the amount of the elevation. Sight is taken from a block at the eye over a block at the jack to the top of these strips. See sketch A.

(6) Digger, Post Hole.—The scissor type should be used in preference to hollow cylinder or auger.

(7) Drills, Track.—For yard construction and switch work the crank power drill should be used, supplied to foreman from supervisor's headquarters. For regular section work a ratchet drill will be sufficient.

(8) Gauges.—The gauging surfaces should be arcs of circles, the radius of which is gauge of track. This prevents any variation through not setting gauge at right angles.

(9) Jacks, Light.—For regular section work a light ratchet jack should be used, capacity four to five tons, 10-inch raise.

(10) Jacks, Heavy.—For ballast, surfacing or construction gangs a heavy ratchet or friction jack should be used, capacity 10 tons, raise 16 inches.

(11) Levels.—The board should be thoroughly seasoned. Level tube should be adjustable. One end of board should be fitted with a slide bar and set screws for elevation of curves.

(12) Pick, Tamping.—Tamping end should be 3 inches by ⅝ inch.

(13) Shovels, Track.—These shovels should be No. 2 size. They should have iron handle or iron cuff for handle tamping ties, if used on mud-ballast track.

(b) STANDARD EQUIPMENT FOR GANGS.

I have shown equipment of gangs recommended in tabular form. The quantity will necessarily vary according to force employed and general character of road. (B. P. attached.)

(c) HAND CARS.—TYPES IN USE.

(1) Light Section Cars.—These should be made strong and durable, even at the expense of lightness. The platform should be 4½ feet by 6 feet. Handles, iron; axles, 1⅝ inch. Great attention should be given to see that the axles are set well apart, near end of sills.

(2) Heavy, Extra Gang.—Platform 5 feet 6 inches by 8 feet. Handles, iron; axles, 2 inches. In this case, as above, it is of the utmost importance that the axles be set as far apart as practicable to avoid the pos-

sibility of unequal weight on ends of cars unbalancing it while running. Many serious accidents have occurred from the neglect of this feature in hand-car construction.

(d) PUSH CARS.—TYPES AND USE.

Each section and yard gang should have a push car. Platform, 5½ feet by 7 feet; axles, 2 inches. Axles should be placed as near end of sills as possible, to prevent same from breaking down or sagging.

Rail gangs should be equipped with a rail or "Larry" car. This has rollers at each end for sliding rail on and off. It is very heavily built throughout.

The beds of push cars and rail cars should cover the wheels.

(e) DUMP CARS.

Each section, ballast or dressing-up gang should be equipped with a dumping device to be applied to push cars, which will dump on either side of car and dump quick. The platform shown in Fig. B is recommended. This can be set on any push car, is easily removed and put out of the way when not wanted, and can be dumped in an instant by one man, thus avoiding the danger of working on the main track with a permanent dump car.

For yard gangs permanent dump beds should be furnished for dump cars. These may be side dumps, Fig C, or Fig. D, if cinder pit can be reached.

(f) METHOD USED IN SUPPLYING AND CHECKING USE OF.

(a) In ordering material the foreman should make requisition on the supervisor.

(b) The supervisor should make requisition on the division engineer, or other superior officer, or storekeeper.

(c) Material is sent out directed to supervisor or foreman. A manifest is sent to the supervisor, on which the material is charged against him.

(d) Supervisor should keep book account with each section and charge foreman with all material sent him during month, also should keep account of material released.

(e) Section foreman should make monthly tool report to supervisor, which must check with supervisor's book account.

This report is made on sheet divided into columns as follows:

(1) Description of tools.
(2) Tools on hand first of month.
(3) Number disposed of.
(4) How disposed of.
(5) On hand last of month.

An inventory of all tools is to be taken once every six months. The foreman's report "on hand last of month" must check with this.

In requesting new tools the foreman should be required to return the old tools, or give a satisfactory reason for not doing so.

GENERAL QUESTIONS.

By H. F. Baldwin.

As outlined in the list of subjects assigned to this Committee, the four subdivisions of this heading may well be reduced to one, "*Cleanliness.*"

In the desire to get all the work possible done with the usually small track forces, the importance of cleanliness as applied to track is too often overlooked. In a few minutes at the end of each day's work, a gang can clean up all the material left after the day's work; in a few minutes daily the station agent or his helper (except in very large towns or terminals) can clean up the station grounds and dispose of all refuse and waste; and with proper encouragement from superiors, foremen and agents soon learn to take great pleasure in maintaining clean and neat tracks, station grounds and stations.

Most railroads have to economize, so that while all officers would like to have their tracks clean, on some roads all the money available has to be expended in necessities; but even the poorest can have clean tracks and clean station grounds, though on poorer lines track with grass, or even weeds growing in it must, of necessity, be considered clean.

There often is a legitimate excuse for allowing grass and weeds to grow in tracks, and adjacent to them. but there can be none for allowing scrap, old ties and other rubbish to be scattered about.

Trackmen should clean up after each day's work; once a week each foreman should go over his entire section, pick up all scattered material and carry it to its proper place. Scrap bins should be provided at each tool house. Once a month all scrap, including car material, etc., from each section should be loaded into cars and shipped to the proper headquarters. usually to where the larger shops are located.

Grass and weeds should be cleaned out of tracks and ditches and to the top lines of embankment at least once a year, where, because of the character of the ballast, the growth of grass and weeds is unusually rapid. This should be done twice each season, preferably in this climate in June and October.

Once a year the weeds and high grass should be mowed within the right-of-way limits, and burned as soon thereafter as they are dry enough. This should always be done while they are green and before the seeds of weeds have ripened. The time for mowing varies with the climate—from June in some sections of the country to early in September in others. In some localities, where the growth of weeds is very rapid, this mowing is necessary twice each season. Where weeds and grass are killed by frost, and where snow does not prevent it, the right-of-way should be burned over in winter.

Boxes, baskets or cans should be furnished at each station to be used as receptacles for scrap paper. etc. The patrons appreciate them, and many, who otherwise would throw paper on floors or platforms of the stations, or onto the tracks, soon learn to use these receptacles.

Whatever cleaning of station grounds cannot be done by the station agent, or his helper, should be done by trackmen. Where track walkers are employed they should be required to keep station grounds clean, at places where the agent cannot do the work, and at such places if trackwalkers are not employed, the track foremen should clean the station grounds thoroughly at least twice a week; but agents should understand always that they alone are responsible for the cleanliness of stations and station grounds.

Painting should be done often enough to keep the buildings looking clean and well preserved. Buildings and signboards generally should be painted once in three years; where light colors are used—especially on lines of heavy traffic which use soft coal—perhaps twice as often.

Semaphores, switch targets, etc., should be painted once a year under favorable conditions, and twice a year under unfavorable conditions.

Wing fences at cattle-guards, fences around section houses, etc., and stock-pen fences should be whitewashed once each season, preferably in summer, and before the fall rains.

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Committee.